

KANSAS-LOWER REPUBLICAN RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Republican River from Hardy, Nebraska to Rice, Kansas
Water Quality Impairment: Total Phosphorous

1. INTRODUCTION

Subbasin: Middle Republican and Lower Republican

Counties: Cloud (CD), Jewell (JW), Republic (RP), Smith (SM)

HUC8: 10250016

HUC10 (12): 04 (08, 09), 05 (01, 03, 04, 07), 06 (02, 04, 05), 07 (08), 08 (01, 02, 03, 04, 05), 09 (01, 02, 03)

10250017

01 (01, 02, 03, 04, 05, 06, 07), 02 (01, 02, 03, 04, 05), 03 (01, 02, 03, 04, 10)

Ecoregions: Central Great Plains (27), Smoky Hills (a) and Rolling Plains and Breaks (b)

Drainage Area: 908.5 square miles (mi²)

Water Quality Limited Segments and Designated Uses (Table 1; Figure 1; Table 2):

Table 1. Main stem and tributary water quality limited segments in the Republican River from Hardy, Nebraska to Rice.

Main Stem	Tributary	Main Stem	Tributary
<i>HUC8 10250016</i>		<i>HUC8 10250017</i>	
Republican River (2)	Walnut Cr (40)	Republican River (26)	Beaver Cr (45)
	Buffalo Cr (59)		Buffalo Cr, Middle (9037)
	Louisa Cr (61)		Buffalo Cr, East (68)
	Cedar Cr (63)		Buffalo Cr (37)
	Oak Cr (75)		Marsh Cr, East (42)
	Crosby Cr (77)		Marsh Cr (35)
Republican River (1)	Spring Cr (78)		Marsh Cr, West (36)
	Bean Cr (76)		Marsh Cr (34)
	White Rock Cr (41)		Marsh Cr (30)
	Otter Cr (79)		Cheyenne Cr (55)
	Dry Cr (80)		Whites Cr (54)
			Buffalo Cr (29)
			Wolf Cr (38)
			Hay Cr (49)
			Cool Cr (50)

Figure 1. Map of contributing area and water quality impaired segments for the Republican River from Hardy, Nebraska to Rice.

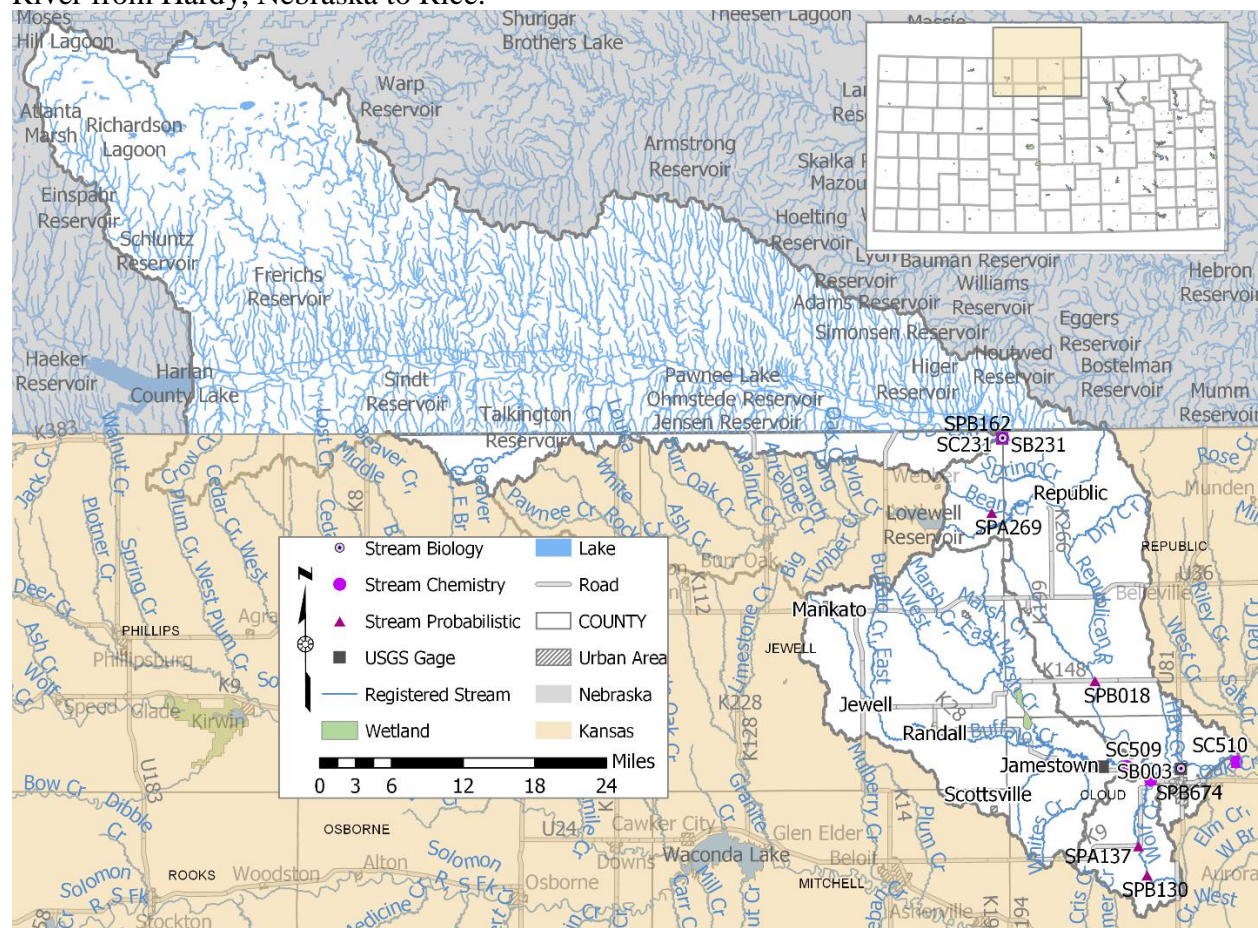


Table 2. Designated uses for main stem and tributary segments on the Republican River from Hardy, Nebraska to Rice (Kansas Surface Water Register, 2013).

Stream	Segment	Aquatic Life	Contact Recreation	Domestic Supply	Food Procurement	Ground-water Recharge	Industrial	Irrigation	Live-stock Watering
<i>HUC8: 10250016</i>									
Walnut Cr	40	E	C	N	N	Y	N	N	N
Buffalo Cr	59	E	C	N	Y	N	N	N	Y
Louisa Cr	61	E	b	N	N	N	N	N	Y
Cedar Cr	63	E	b	N	N	N	N	N	N
Oak Cr	75	E	b	Y	Y	Y	Y	Y	Y
Crosby Cr	77	E	C	N	Y	Y	N	Y	N
Republican R	2	E	b	Y	Y	Y	Y	Y	Y
Spring Cr	78	E	b	Y	N	Y	Y	Y	Y
Bean Cr	76	E	b	Y	N	Y	Y	Y	Y
White Rock Cr	41	E	C	Y	Y	Y	Y	Y	Y
Otter Cr	79	E	b	N	N	Y	N	Y	Y
Dry Cr	80	E	b	Y	Y	Y	Y	Y	Y
Republican R	1	E	b	Y	Y	Y	Y	Y	Y

Stream	Segment	Aquatic Life	Contact Recreation	Domestic Supply	Food Procurement	Ground-water Recharge	Industrial	Irrigation	Live-stock Watering
<i>HUC8: 10250017</i>									
Beaver Cr	45	E	b	Y	N	Y	Y	Y	Y
Republican R	28	E	C	Y	Y	Y	Y	Y	Y
Buffalo Cr, Middle	9037	E	b	N	Y	Y	N	Y	Y
Buffalo Cr, East	68	E	b	N	N	Y	N	Y	Y
Buffalo Cr	37	E	b	Y	Y	Y	Y	Y	Y
Marsh Cr, East	42	E	b	N	Y	N	N	Y	Y
Marsh Cr	35	E	a	N	Y	Y	N	Y	Y
Marsh Cr, West	36	E	b	N	Y	N	N	Y	Y
Marsh Cr	34	E	C	Y	Y	Y	Y	Y	Y
Marsh Cr	30	E	C	N	Y	Y	N	Y	Y
Cheyenne Cr	55	E	b	N	N	Y	N	Y	Y
Whites Cr	54	E	b	N	Y	Y	N	Y	Y
Buffalo Cr	29	E	b	N	Y	Y	N	Y	Y
Wolf Cr	38	E	C	Y	Y	Y	Y	Y	Y
Hay Cr	49	E	b	N	N	Y	N	Y	Y
Cool Cr	50	E	b	N	N	Y	N	Y	Y
Republican R	26	E	B	Y	Y	Y	Y	Y	Y

Definitions: E - Expected aquatic life use water; B, C - Primary contact recreation stream; N - Referenced stream segment does not support the indicated designated use; Y - Referenced stream segment is assigned the indicated designated use; a, b - Secondary contact recreation stream

303(d) Listings for Total Phosphorus, Biology, Dissolved Oxygen, and pH

Republican River near Hardy, Nebraska (SC231; **Figure 2**)

Total phosphorus, category 5: 2008, 2010, 2012, 2014, 2016, and 2018

Biology, category 5: 2002, 2004, 2008, 2010, 2012, 2014, 2016, and 2018

pH, category 3: 2008 and 2010

pH, category 2: 2012, 2014, 2016, and 2018

Buffalo Creek near Concordia (SC509; **Figure 2**)

Total phosphorus, category 5: 2008, 2010, 2012, 2014, 2016, and 2018

Wolf Creek near Concordia (SC707; **Figure 2**)

Total phosphorus, category 5: 2008, 2010, 2012, 2014, 2016, and 2018

Dissolved oxygen, category 5: 2012, 2014, 2016, and 2018

Republican River near Rice (SC510; **Figure 2**)

Total phosphorus, category 5: 2008, 2010, 2012, 2014, 2016, and 2018

Biology, category 5: 2018

Biology, category 3: 2016

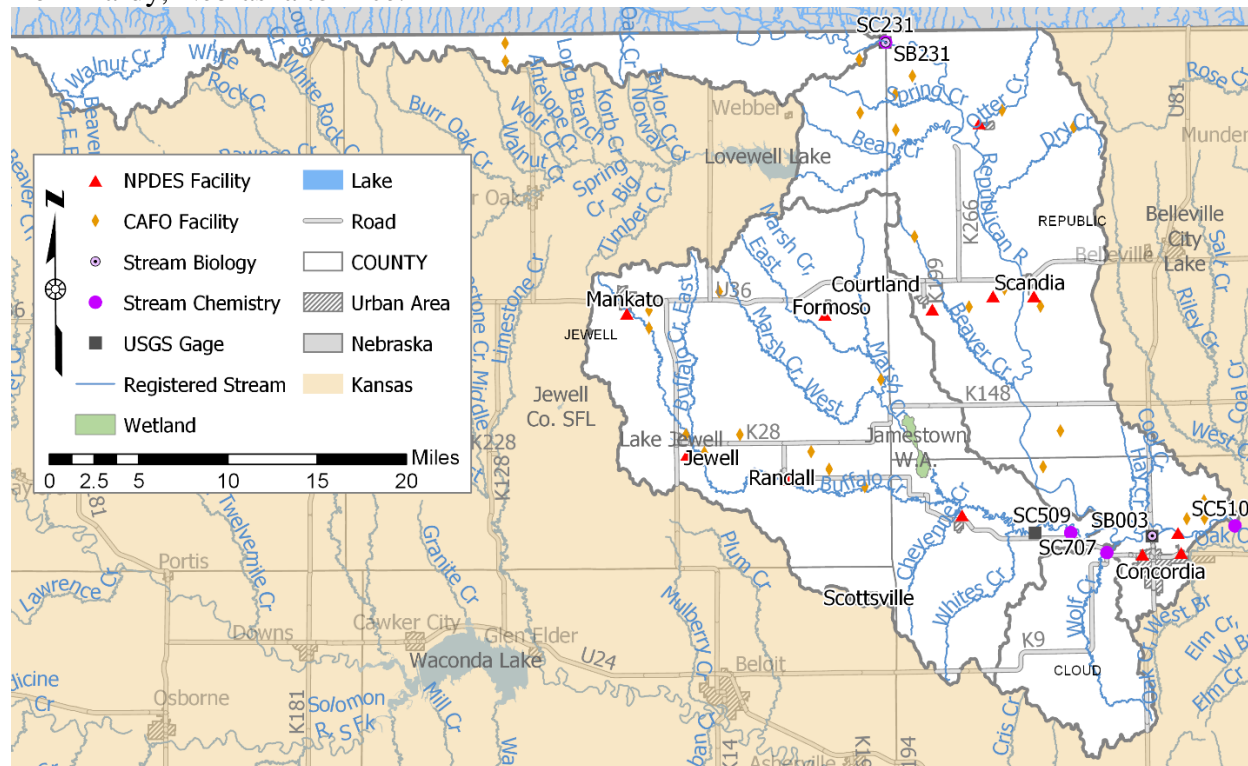
pH, category 5: 2004, 2008, and 2010

pH, category 3: 2014

pH, category 2: 2012, 2016, and 2018

Impaired Uses: Expected aquatic life, contact recreation, and domestic water supply

Figure 2. Map of contributing area and facilities for Kansas Department of Health and Environment stream chemistry (SC) and stream biology (SB) stations for the Republican River from Hardy, Nebraska to Rice.



Water Quality Criteria

Narrative Nutrient Criteria

The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(d)(3)(D)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (K.A.R. 28-16-28e(d)(7)(A)).

Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (K.A.R. 28-16-28e(b)(7)).

Numeric Dissolved Oxygen Criteria

The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. The Dissolved Oxygen criterion is 5.0 mg/L (K.A.R. 28-16-28e(e), Table 1g).

Numeric pH Criteria

Artificial sources of pollution shall not cause the pH of any surface water outside of a zone of initial dilution to be below 6.5 and above 8.5 (K.A.R. 28-16-28e(e), Table 1g).

2. CURRENT WATER QUALITY CONDITIONS AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2018 303(d)

Phosphorus levels in the Republican River from Hardy, NE to Rice are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, contact recreation, and domestic water supply. The ultimate endpoint of this Total Maximum Daily Load (TMDL) will be to achieve the Kansas Surface Water Quality Standards by eliminating excessive primary productivity and impairment to aquatic life, recreation, and domestic water supply associated with excessive phosphorus.

Station Location and Period of Record

Stream Chemistry (SC) Monitoring Stations

SC231: Active permanent station for the Republican River near Hardy, Nebraska, located at latitude 39.992, longitude -97.932. Period of record: March 13, 1990 to October 16, 2018.

SC509: Active permanent station for Buffalo Creek near Concordia, located at latitude 39.592, longitude -97.743. Period of record: March 13, 1990 to October 16, 2018.

SC707: Active rotational station for Wolf Creek near Concordia, located at latitude 39.575, longitude -97.706. Period of record: January 10, 1994 to October 16, 2018.

SC510: Active permanent station for the Republican River near Rice, located at latitude 39.596, longitude -97.571. Period of record: March 13, 1990 to October 16, 2018.

Stream Biology (SB) Monitoring Stations

SB231: Active permanent station for the Republican River near Hardy, Nebraska, located at latitude 39.992, longitude -97.932. Period of record: November 1, 1990 to June 27, 2017.

SB003: Active station for the Republican River at Concordia, located at latitude 39.589, longitude -97.658. Period of record: June 5, 2013 to June 27, 2017.

Stream Probabilistic (SP) Monitoring Stations

SPA137: Wolf Creek. Period of record: 2007.

SPB130: Wolf Creek. Period of record: 2011.

SPB674: Wolf Creek. Period of record: 2017.

Streamflow Gages

U.S. Geological Survey gage Republican River near Hardy, Nebraska (06853500). Period of record: January 1, 1990 to December 31, 2018. Located at Republican River near Hardy, NE (SC231).

U.S. Geological Survey gage Buffalo Creek four miles east of Jamestown (06855850). Period of record: June 4, 2014 to December 31, 2018. Located near Buffalo Creek near Concordia (SC509).

U.S. Geological Survey gage Salt Creek near Ada (06876700). Period of record: January 1, 1990 to December 31, 2018. Located near Buffalo Creek near Concordia (SC509) and used to estimate Buffalo Creek flow based upon a watershed ratio.

U.S. Geological Survey gage Republican River at Concordia (06856000). Period of record: January 1, 1990 to December 31, 2018. Located near Republican River near Rice (SC510).

Hydrology

Flow conditions for this TMDL were analyzed using U.S. Geological Survey (USGS) streamgage data from the Republican River near Hardy, Nebraska (NE; 06853500), Buffalo Creek four miles east of Jamestown (06855850), Salt Creek near Ada (06876700), and Republican River at Concordia (06856000). The Republican River and Salt Creek gages have streamflow data available for the period of record January 1, 1990 to December 31, 2018. The Buffalo Creek gage has streamflow data available for the period of record June 4, 2014 to December 31, 2018.

Flow conditions for the Kansas Department of Health and Environment (KDHE) stream chemistry (SC) station Republican River near Hardy, NE (SC231) is based upon streamflow measurements at the USGS Republican River near Hardy, NE (06853500) streamgage (**Table 3**). Flow conditions for the Buffalo Creek near Concordia (SC509) were calculated using a watershed area ratio based upon the USGS Salt Creek near Ada (06876700) streamgage and its drainage area; streamflow estimations for this station were corroborated with available USGS data from Buffalo Creek four miles east of Jamestown (06855850). Flow conditions for the Wolf Creek near Concordia (SC707) and Republican River near Rice (SC510) were calculated using a watershed area ratio based upon the USGS Republican River at Concordia (06856000) streamgage and its drainage area.

Flow duration curves for the KDHE stations Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510) are displayed in **Figure 3**. Streamflow for the largest tributary watershed, Buffalo Creek near Concordia (SC509), is approximately 10 times lower than streamflows at main stem stations for the Republican River near Hardy, NE (SC231) and Rice (SC510). Meanwhile, streamflow for the smallest tributary watershed, Wolf Creek near Concordia (SC707), is over 100 times lower than streamflows at main stem stations for the Republican River near Hardy, NE (SC231) and Rice (SC510; **Table 3**). Long-term estimated flows for the Republican River and its tributaries can be found in **Table 4** (Perry et al., 2004). The largest tributaries for the Buffalo Creek near Concordia (SC509) are Cheyenne Creek and White Creek. The largest tributaries for the Republican River near Rice (SC510) are Beaver Creek, Buffalo Creek, and Wolf Creek.

Table 3. Flow conditions and drainage area at U.S. Geological Survey gages and Kansas Department of Health and Environment stream chemistry (SC) stations for the Republican River from Hardy, NE to Rice.

Stream	Station	Contributing Drainage Area (mi ²)	Mean Flow (cfs)	Percent Flow Exceedance (CFS)				
				90%	75%	50%	25%	10%
Republican R nr Hardy, NE	06853500/SC231	14,901	223	22.2	37.7	111	209	492
Buffalo Cr nr Concordia	SC509	386.9	64.7	1.91	4.49	12.0	29.0	100
Wolf Cr nr Concordia	SC707	66.1	1.71	0.18	0.34	0.78	1.57	3.75
Republican R at Concordia	06856000	16,060	416	44.0	83.4	189	381	912
Republican R nr Rice	SC510	16,086	417	44.1	83.5	189	382	913

Figure 3. Flow duration curves for Kansas Department of Health and Environment stream chemistry (SC) stations Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510) based upon U.S. Geological Survey (USGS) gaged sites located in the Republican River (06853500 and 06856000) and Salt Creek (06876700).

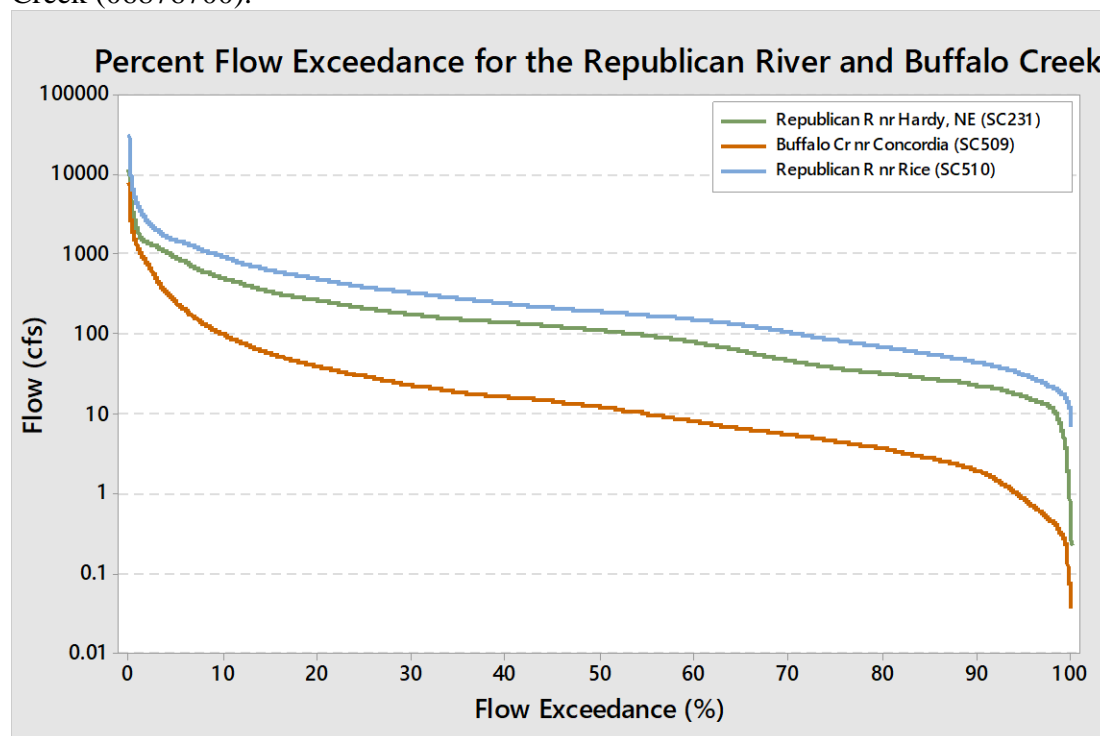


Table 4. Long-term estimated flows from the U.S. Geological Survey (USGS) for the Republican River from Hardy, NE to Rice and its tributaries (Perry et al., 2004).

Stream	USGS Site	KSWR CUSEGA Number	County	Drainage Area (mi ²)	Mean Flow (CFS)	Percent Flow Exceedance (CFS)					2-year Peak (CFS)
						90%	75%	50%	25%	10%	
Walnut Cr	93	1025001640	SM	24.3	2.79	0	0	0.22	0.49	1.71	724
Buffalo Cr	35	1025001659	SM	5.55	0	0	0	0	0	0	318
Louisa Cr	33	1025001661	SM	3.62	0	0	0	0	0	0	269
Cedar Cr	30	1025001663	SM	3.91	0	0	0	0	0	0	289
Oak Cr	46	1025001675	JW	7.00	0.88	0	0	0	0	0	451
Republican R	111	102500162	JW	20,600	324	59.1	106	163	298	709	4,870
Crosby Cr	107	1025001677	JW	11.0	1.93	0	0	0.04	0.08	0.82	607
Republican R	118	102500162	JW, RP	20,600	333	63.0	110	167	307	728	4,940
Spring Cr	170	1025001678	JW, RP	18.3	3.07	0	0	0.25	0.47	1.91	820
Republican R	208	102500161	RP	20,600	346	68.2	114	174	328	762	5,080
Bean Cr	262	1025001676	JW, RP	20.7	4.05	0	0	0.61	1.27	3.49	881
White Rock Cr	260	1025001641	RP	383	34.1	0.30	0.41	0.68	1.63	57.1	472
Republican R	234	102500161	RP	21,000	456	109	147	230	494	1,030	6,170
Otter Cr	233	1025001679	RP	36.0	7.27	0	0	0.84	2.34	6.91	1,190
Republican R	358	102500161	RP	21,100	469	115	151	237	515	1,070	6,310
Dry Cr	357	1025001680	RP	30.4	7.60	0	0.48	1.68	3.64	8.60	965
Republican R	563	1025001728	RP	21,200	488	120	156	246	539	1,110	6,460
Beaver Cr	564	1025001745	RP	46.5	8.25	0	0	0.67	2.25	7.39	832
Republican R	789	1025001728	CD	21,200	502	119	158	252	545	1,130	6,500
Marsh Cr, East	515	1025001742	JW	38.3	8.53	0	0.22	1.58	3.96	10.1	1,130
Marsh Cr	566	1025001735	JW	78.2	16.8	0	0.72	2.99	8.31	22.2	1,570
Marsh Cr, West	613	1025001736	JW	44.1	8.85	0	0.09	1.34	3.63	9.96	1,010
Marsh Cr	625	1025001734	JW, RP	129	26.90	0	1.33	4.71	13.9	38.9	1,790
Marsh Cr	750	1025001730	CD	142	29.6	0	1.53	5.23	15.6	43.8	1,570
Buffalo Cr, East	637	1025001768	JW	25.8	5.72	0	0.08	1.08	2.46	6.19	998
Buffalo Cr	759	1025001737	CD	154	31.4	0	1.78	5.76	17.0	47.6	1,550
Cheyenne Cr	909	1025001755	CD	40.9	8.06	0	0	1.15	3.18	8.87	1,030
Whites Cr	939	1025001754	CD	46.2	10.2	0	0.21	1.74	4.51	11.6	1,230
Buffalo Cr	802	1025001729	CD	405	83.1	1.4	4.21	14.0	48.3	152	1,640
Republican R	806	1025001726	CD	21,700	565	114	168	279	572	1,230	6,680
Wolf Cr	874	1025001738	CD	59.6	11.0	0	0.10	1.00	4.30	17.0	910
Republican R	805	1025001726	CD	21,700	574	113	170	283	576	1,250	6,710
Hay Cr	796	1025001749	CD, RP	19.3	5.37	0	0.31	1.30	2.61	6.02	943
Republican R	797	1025001726	CD	21,700	577	113	170	284	577	1,250	6,720
Cool Cr	792	1025001750	CD, RP	11.9	3.05	0	0.20	0.74	1.16	2.74	720
Republican R	816	1025001726	CD	21,800	588	114	172	288	587	1,270	6,900

Definitions: SM - Smith; JW - Jewell; RP - Republic; CD - Cloud

Quantifying streamflow within this watershed is complicated by the presence of the Courtland Canal and Lovewell Reservoir. Courtland Canal and Lovewell Reservoir were built by the Bureau of Reclamation in order to service the Kansas Bostwick Irrigation District (KBID; Hansen, 1997). Releases from Harlan County Dam in Nebraska flow to the Republican River and are diverted by the Superior-Courtland Diversion Dam at Guide Rock, NE. These releases are then diverted to the Courtland Canal and stored in Lovewell Reservoir until their release is requested by KBID. This system is 114 miles in length and is used to irrigate 62,000 acres in Kansas (Bureau of Reclamation, 2019). Of the watersheds discussed in this document, the majority of this acreage is west of the Republican River, along Buffalo and White Rock creeks. Additionally, both surface water from the Republican River and groundwater diversions are key components of water use in these watersheds, predominantly for the purpose of irrigation.

The highest mean annual flows for the Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510) occurred in 1993 with flows of: 1,028; 433; and 2,178 cubic feet per second (cfs), respectively (**Figures 4-6**). The highest median annual flows also occurred in 1993 with flows of: 652; 112; and 1,322 cfs, respectively. Annual mean and median flows were lowest in 2006 for all stations, as well, with the exception of the median at Buffalo Creek near Concordia (SC509). The lowest mean and median annual flows were: 20 and 18 cfs, respectively, for the Republican River near Hardy, NE (SC231); 4.8 and 2.38 (1991) cfs, respectively, for the Buffalo Creek near Concordia (SC509); and 44 and 35 cfs, respectively, for the Republican River near Rice (SC510).

Figure 4. Annual mean and median flows for the Republican River near Hardy, NE (SC231) and annual total precipitation at National Oceanic and Atmospheric Association station USC00258320 at Superior, NE.

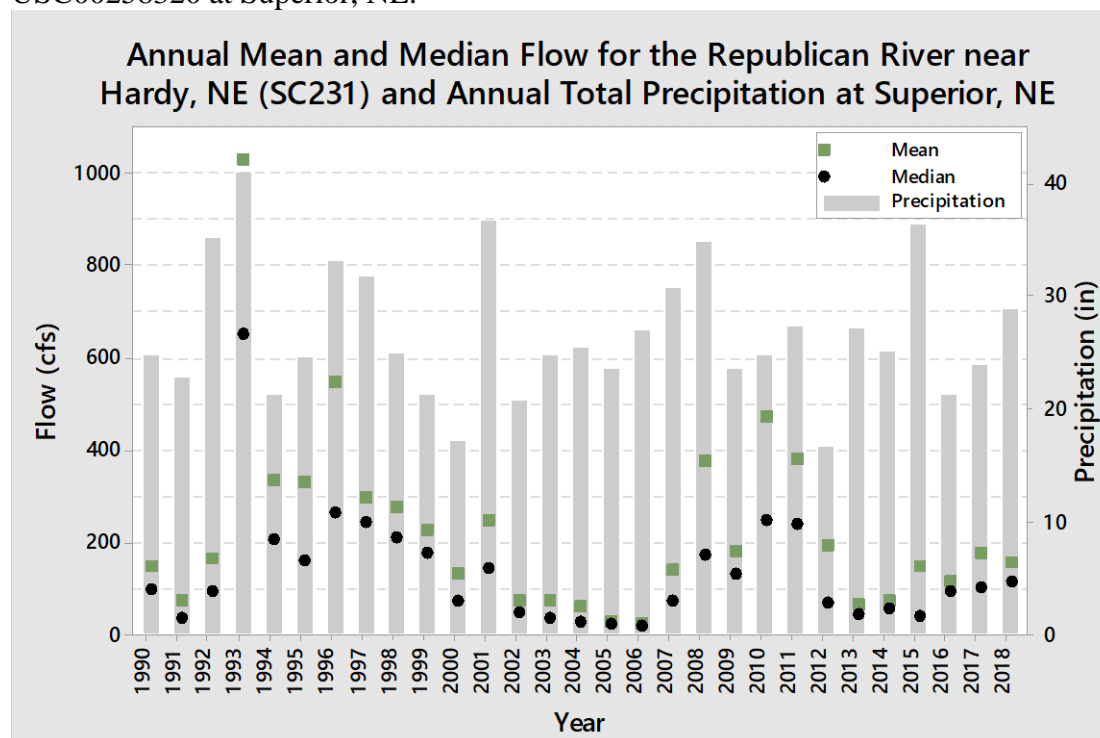


Figure 5. Annual mean and median flows for the Buffalo Creek near Concordia (SC509) and annual total precipitation at National Oceanic and Atmospheric Association station USC00144089 at Jewell.

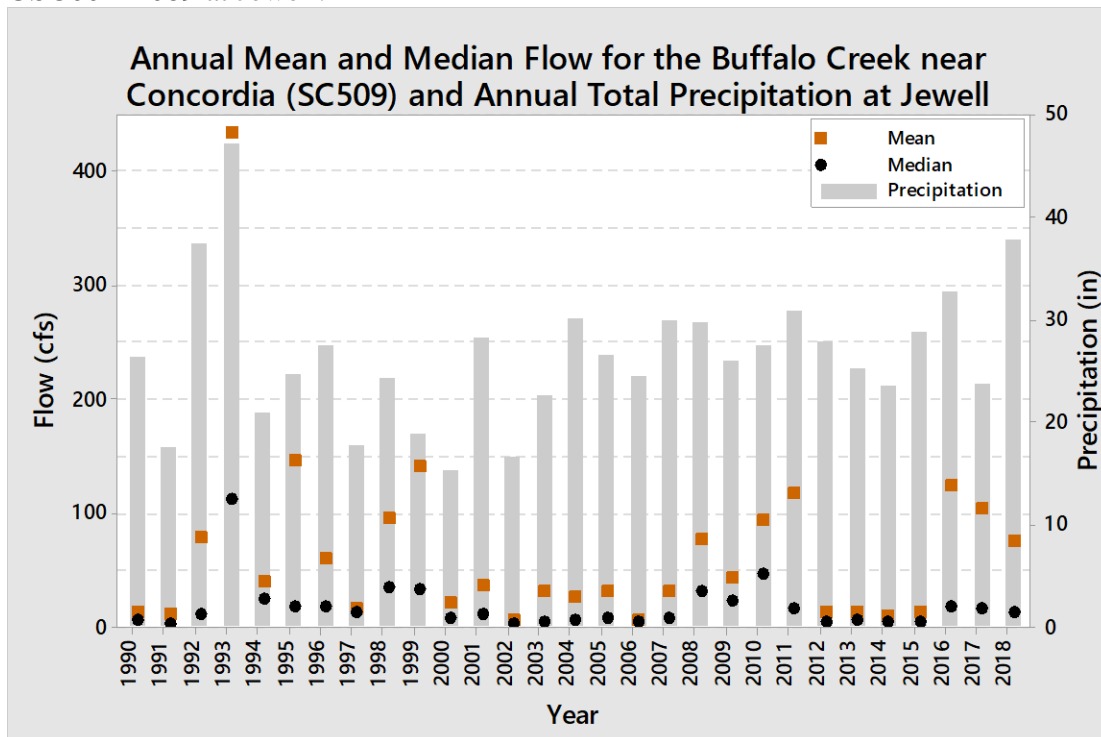
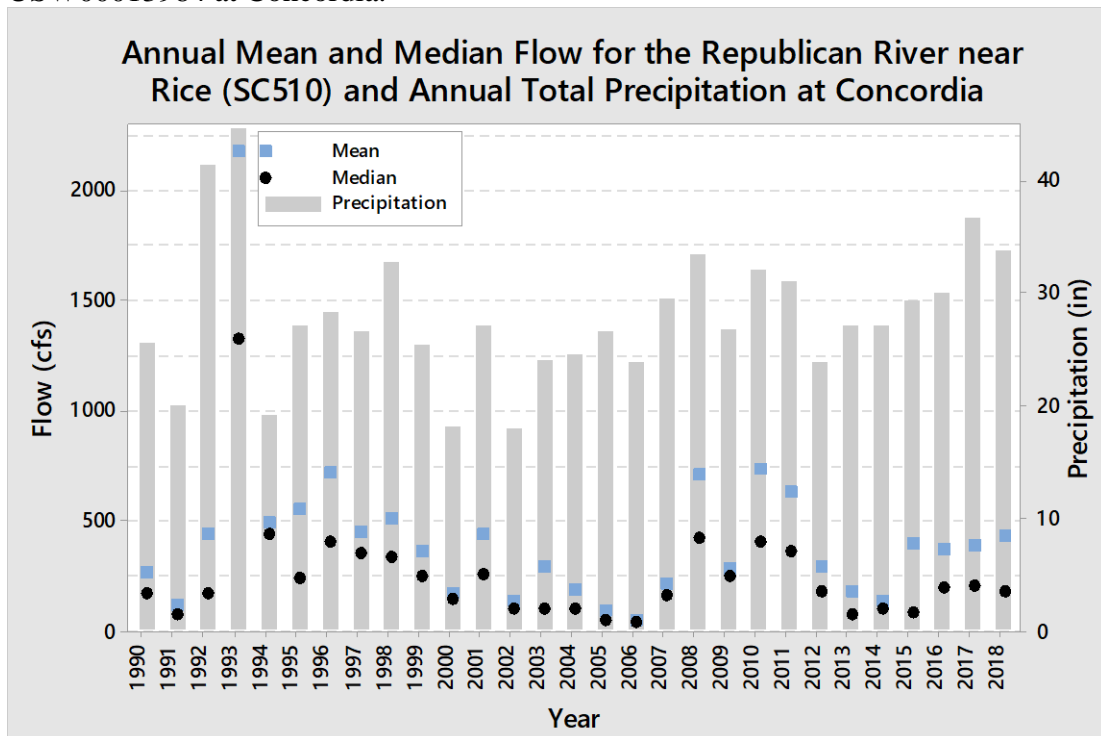


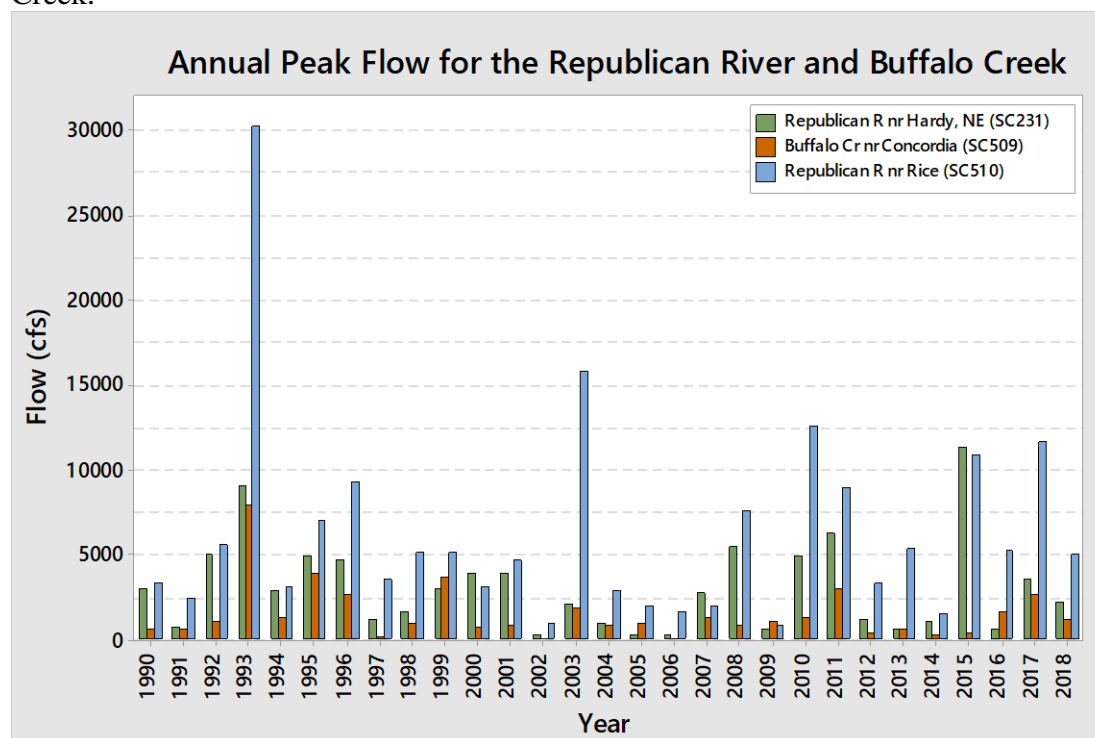
Figure 6. Annual mean and median flows for the Republican River near Rice (SC510) and annual total precipitation at National Oceanic and Atmospheric Association station USW00013984 at Concordia.



Trends in annual flows for the Republican River near Hardy, NE (SC231) and Rice (SC510) generally coincide with National Oceanic and Atmospheric Administration (NOAA) annual total precipitation from stations USC00258320 at Superior, NE and USW00013984 at Concordia, respectively. Trends in annual flows for the Buffalo Creek near Concordia (SC509) are more variable but can coincide with NOAA annual total precipitation from stations USC00144089 at Jewell. The highest annual precipitation for all stations occurred in 1993, corresponding to the year with the highest annual flows.

The most consistent peak annual flow among the Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510) occurred in 1993, with flows of: 9,080; 7,881; and 30,249 cfs, respectively (**Figure 7**). The Republican River near Hardy, NE (SC231) also had a notable peak of 10,818 cfs in 2015, while the Republican River near Rice (SC510) had notable peaks in 2003, 2010, 2015, and 2017. Significant peaks in flow for the Republican River near Rice (SC510) during 2003, 2010, and 2015 may be more heavily influenced by releases from Lovewell Reservoir or a decrease in irrigation diversions directly from the Republican River during these years.

Figure 7. Annual peak flows for the Republican River from Hardy, NE to Rice and Buffalo Creek.



Seasonally for the Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510), high flows occur in spring (April through June) and are skewed by high flow events, likely due to increased precipitation and runoff events (**Figures 8-10**). Winter (November through March) and summer-fall (July through October) flows tend to be lower and similar between the two seasons for all stations, though mean summer-fall flows are higher than winter mean flows.

Figure 8. Flow by season for the Republican River near Hardy, NE (SC231).

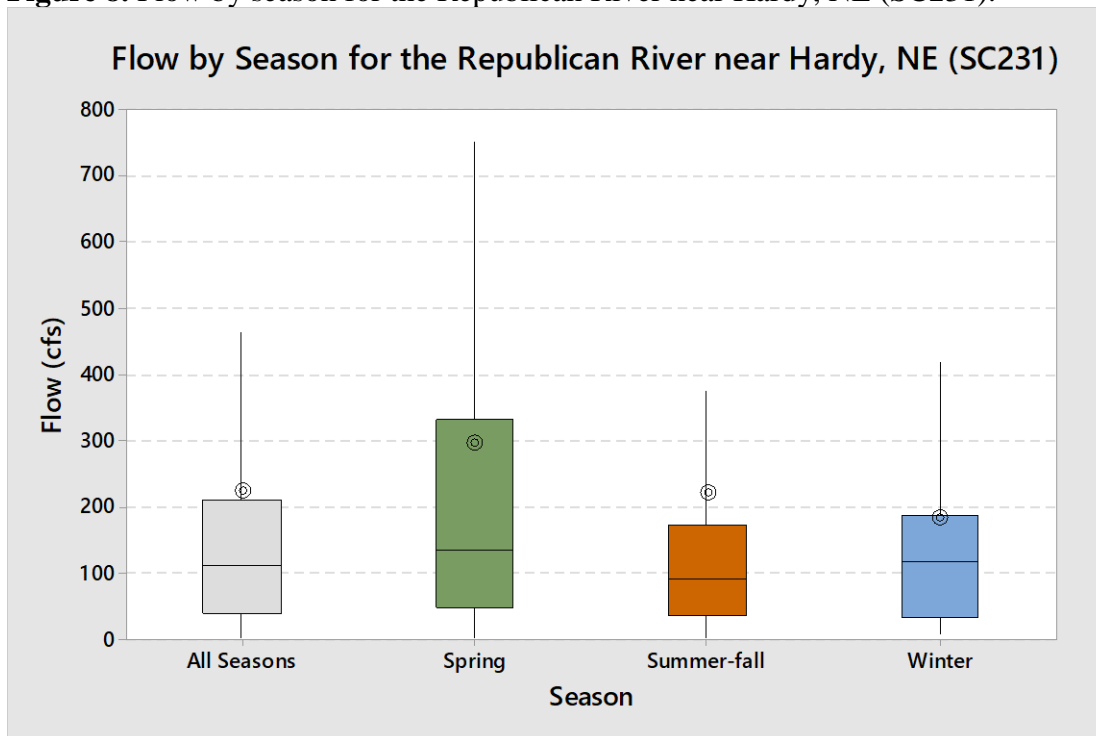


Figure 9. Flow by season for the Buffalo Creek near Concordia (SC509).

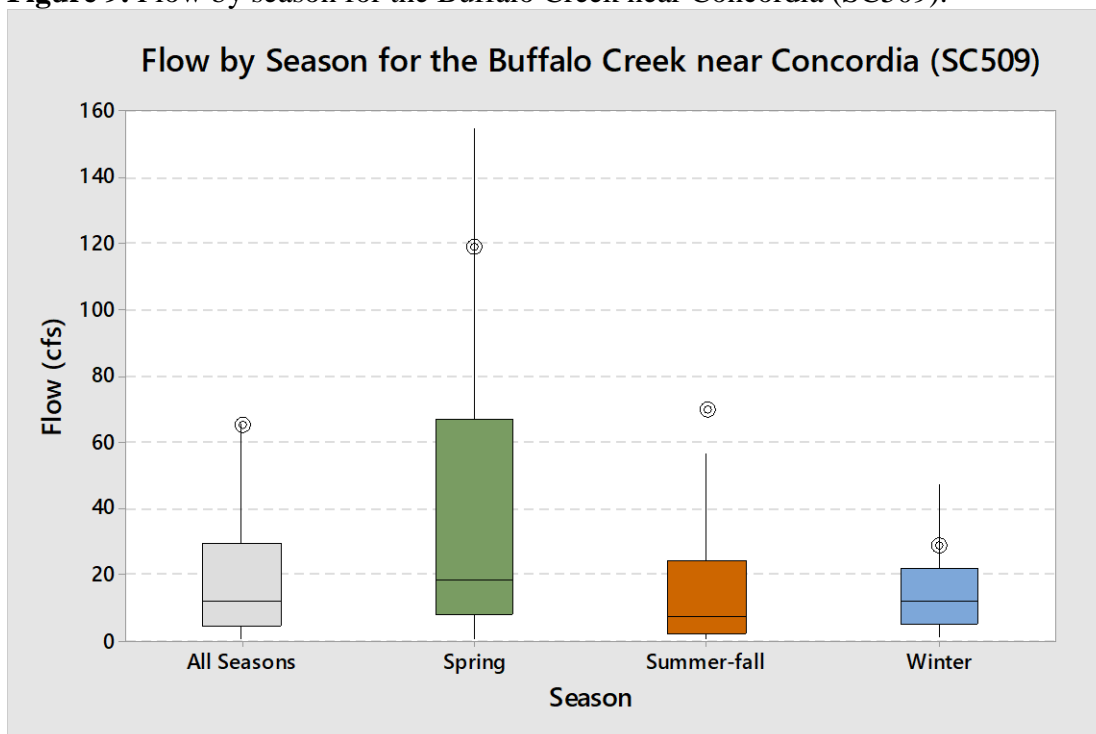
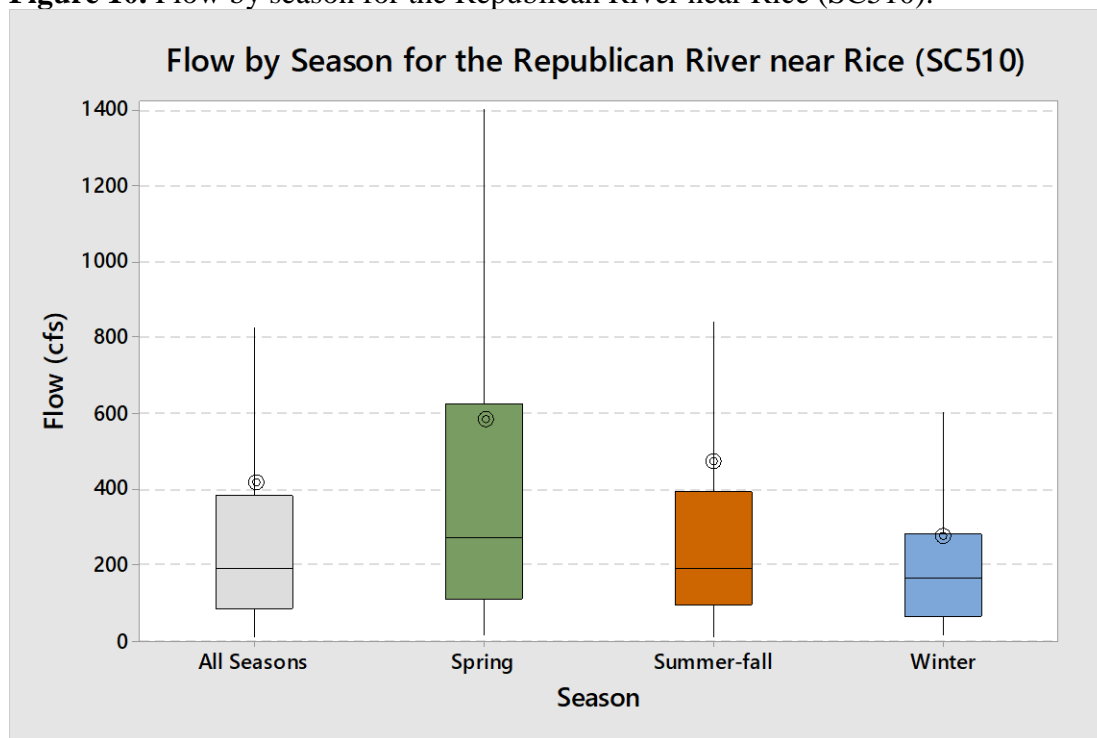


Figure 10. Flow by season for the Republican River near Rice (SC510).



Total Phosphorus Concentrations

Overall, total phosphorus (TP) concentrations for the Republican River from Hardy, NE to Rice increase among the downstream stations in Kansas from the upstream station in Nebraska (**Figure 11**). While mean and median TP concentrations increase slightly along the main stem stations Republican River near Hardy, NE (SC231) and Rice (SC510), mean and median TP concentrations increase dramatically at the tributary stations Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707). Of all the stations, Buffalo Creek near Concordia (SC509) has the highest mean and median TP concentrations.

The range of SC station TP concentrations is from 0.070 milligrams per liter (mg/L) for the Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707) stations to 2.59 mg/L for the Republican River near Hardy, NE (SC231; **Table 5**). Among the stations, the main stem Republican River stations have the most similar means and medians: Republican River near Hardy, NE (SC231) has a mean of 0.333 mg/L and a median of 0.253 mg/L; Republican River near Rice (SC510) has a mean of 0.371 mg/L and a median of 0.287 mg/L. Buffalo Creek near Concordia (SC509) has the highest means and medians of all the SC stations, with a mean of 0.498 mg/L and a median of 0.422 mg/L. Wolf Creek near Concordia (SC707) has the most variability between mean and median TP concentrations, with a mean of 0.455 mg/L and a median of 0.360 mg/L. This variability is also captured by differences between the stream probabilistic (SP) station samples collected along the Wolf Creek (SPA137 and SPB130). Samples collected at station SPA137, which had four samples collected in 2007, have a mean of 0.845 mg/L, while samples collected at station SPB130, which had four samples collected in 2011, have a mean of 0.152 mg/L. It should also be noted that Wolf Creek near Concordia (SC707) has the fewest number of samples due to the rotational collection of data at this station.

Figure 11. Total phosphorus by station from 1990 to 2018 for the Republican River from Hardy, NE to Rice.

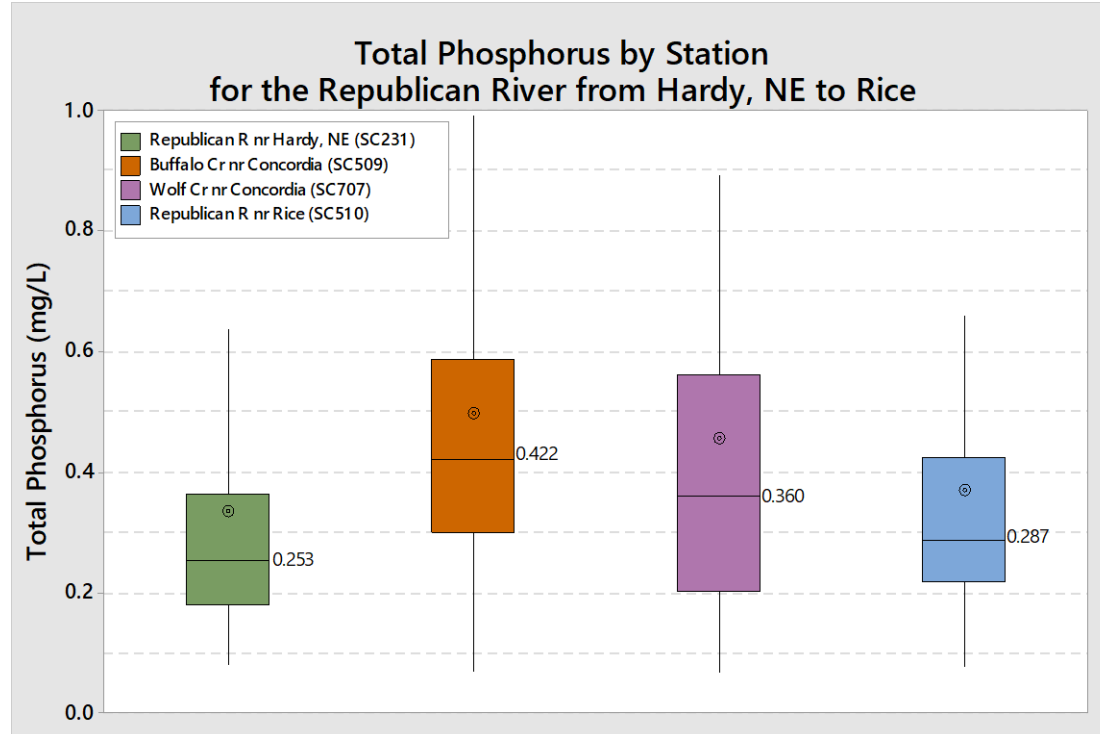


Table 5. Total phosphorus concentration mean, median, maximum, minimum, and number of samples (N) by station from 1990 to 2018 for the Republican River from Hardy, NE to Rice.

Station	Total Phosphorus Mean (mg/L)	Total Phosphorus Median (mg/L)	Total Phosphorus Maximum (mg/L)	Total Phosphorus Minimum (mg/L)	N
Republican R nr Hardy, NE (SC231)	0.333	0.253	2.59	0.081	148
Buffalo Cr nr Concordia (SC509)	0.498	0.422	2.06	0.070	148
Wolf Cr (SPA137)	0.845	—	—	—	4
Wolf Cr (SPB130)	0.152	—	—	—	4
Wolf Cr nr Concordia (SC707)	0.455	0.360	1.95	0.070	37
Republican R nr Rice (SC510)	0.371	0.287	1.70	0.077	148

Definition: — No data

To further assess TP load sources for the Republican River from Hardy, NE to Rice, a mass balance was estimated based upon mean TP concentrations and streamflow for each watershed (Perry, 2004; **Table 6**). The total load is accumulative and reflects the total TP load at each station in pounds per day (lbs/day). The total load by watershed is incremental and reflects the total TP load contributed within each watershed. The mass balance calculation suggests that 51% of the load reaching the Republican River near Rice (SC510) originates above the Republican River near Hardy, NE (SC231). The Republican River near Hardy, NE (SC231) station is not within Kansas jurisdiction and Kansas cannot account for TP loads emanating above this station; however, the Republican River near Hardy, NE (SC231) is considered in this

analysis for comparison purposes and to identify sources of TP loading. Of the remaining 49% of TP load, the majority is contributed by the watersheds for the Buffalo Creek near Concordia (SC509) and the Republican River near Rice (SC510), which contribute 19 and 28% of the TP load, respectively.

Table 6. Estimated mass balance for total phosphorus loads based upon mean streamflow (Perry, 2004) for the Republican River from Hardy, NE to Rice.

Station	Drainage Area (mi ²)	Mean Flow (cfs)	Mean Total Phosphorus (mg/L)	Total Phosphorus Load (lbs/day)	Total Phosphorus Load by Watershed (lbs/day)	Percent of Total Load (%)
Republican R (SC231) nr Hardy, NE	20,600	333	0.333	599	599	51
Buffalo Cr (SC509)	405	83.1	0.498	224	224	19
Wolf Cr (SC707)	59.6	11.0	0.455	27.0	27.0	2
Republican R (SC510) nr Rice	21,800	588	0.371	1,180	328	28
Total	21,800	588	0.371	1,180	0	100

Definition: **Bold** - Main stem station

Annual trends for medians for the Republican River from Hardy, NE to Rice indicate that TP concentrations are increasing in all Kansas watersheds (**Table 7**). This trend is especially strong when comparing medians from 1990 to 1999 with medians from 2000 to 2018. For these delineations, the only station with a decrease in TP concentrations is the Republican River near Hardy, NE (SC231) which has concentrations of 0.256 mg/L from 1990 to 1999 and 0.240 mg/L from 2000 to 2018. Over the same periods, the Buffalo Creek near Concordia (SC509), Wolf Creek near Concordia (SC707), and Republican River near Rice (SC510) have all increased their median TP concentrations by 0.073, 0.107, and 0.018 mg/L, respectively. Annual trends for means are more variable for the same periods of record, with mean TP concentrations increasing for the Republican River near Hardy, NE (SC231) and Buffalo Creek near Concordia (SC509) and decreasing for the Wolf Creek near Concordia (SC707) and Republican River near Rice (SC510).

Annually, the highest mean TP concentrations occurred in: 2012 for the Republican River near Hardy, NE (SC231), with a mean of 0.820 mg/L; 2015 for the Buffalo Creek near Concordia (SC509), with a mean of 0.805 mg/L; 2006 for the Wolf Creek near Concordia (SC707), with a mean of 0.848 mg/L; and 2016 for the Republican River near Rice (SC510), with a mean of 0.665 mg/L (**Figures 12-15**). Daily samples for all stations display several higher TP concentration samples which are likely influencing mean trends for all stations. The highest median TP concentrations occurred in: 2007 for the Republican River near Hardy, NE (SC231), with a median of 0.616 mg/L; 2015 for the Buffalo Creek near Concordia (SC509), with a median of 0.725 mg/L; 2006 for the Wolf Creek near Concordia (SC707), with a median of 0.833 mg/L; and 2007 for the Republican River near Rice (SC510), with a median of 0.508 mg/L. Available data suggests that the highest mean and median TP concentrations for the tributaries Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707) typically correspond to years with lower streamflow conditions. The TP concentrations in the main stem Republican River near Hardy, NE (SC231) and Rice (SC510) are more variable,

though both have their highest medians in 2007, coinciding with increased annual precipitation after periods of lower streamflow conditions.

Table 7. Total phosphorus concentration annual mean, median, and sample number (N) by station for the Republican River from Hardy, NE to Rice.

Year	Total Phosphorus (mg/L) for Republican R nr Hardy, NE (SC231)			Total Phosphorus (mg/L) for Buffalo Cr nr Concordia (SC509)			Total Phosphorus (mg/L) for Wolf Cr nr Concordia (SC707)			Total Phosphorus (mg/L) for Republican R nr Rice (SC510)		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
1990	0.294	0.290	5	0.366	0.410	5	—	—	—	0.330	0.330	5
1991	0.368	0.355	6	0.388	0.430	6	—	—	—	0.327	0.315	6
1992	0.433	0.285	6	0.655	0.410	6	—	—	—	0.458	0.265	6
1993	0.508	0.420	5	0.326	0.290	5	—	—	—	0.406	0.280	5
1994	0.257	0.200	6	0.635	0.400	6	0.562	0.365	6	0.430	0.245	6
1995	0.247	0.230	5	0.296	0.290	5	—	—	—	0.273	0.267	6
1996	0.282	0.193	5	0.398	0.360	5	—	—	—	0.400	0.284	5
1997	0.258	0.234	6	0.396	0.302	6	—	—	—	0.328	0.276	6
1998	0.297	0.243	6	0.486	0.485	6	0.383	0.213	6	0.553	0.425	6
1999	0.270	0.270	6	0.382	0.320	6	—	—	—	0.327	0.305	6
2000	0.232	0.207	6	0.370	0.325	6	—	—	—	0.243	0.260	6
2001	0.292	0.296	6	0.420	0.413	6	—	—	—	0.296	0.326	6
2002	0.206	0.206	6	0.384	0.317	6	0.444	0.417	6	0.217	0.223	6
2003	0.333	0.240	5	0.452	0.439	5	—	—	—	0.245	0.177	5
2004	0.269	0.178	5	0.448	0.453	5	—	—	—	0.315	0.316	5
2005	0.403	0.200	6	0.482	0.451	6	—	—	—	0.363	0.382	6
2006	0.226	0.193	5	0.455	0.278	5	0.848	0.833	3	0.246	0.207	5
2007	0.611	0.616	6	0.495	0.415	6	—	—	—	0.499	0.508	6
2008	0.461	0.349	6	0.791	0.621	6	—	—	—	0.423	0.322	6
2009	0.215	0.192	5	0.411	0.441	5	—	—	—	0.262	0.214	4
2010	0.251	0.219	4	0.654	0.633	4	0.403	0.375	4	0.391	0.383	4
2011	0.292	0.268	4	0.468	0.528	4	—	—	—	0.373	0.297	4
2012	0.820	0.283	4	0.679	0.593	4	—	—	—	0.504	0.414	4
2013	0.372	0.200	4	0.628	0.402	4	—	—	—	0.443	0.300	4
2014	0.443	0.345	4	0.623	0.565	4	0.480	0.465	4	0.610	0.430	4
2015	0.255	0.170	4	0.805	0.725	4	—	—	—	0.367	0.225	4
2016	0.270	0.260	4	0.772	0.555	4	—	—	—	0.665	0.370	4
2017	0.238	0.250	4	0.528	0.505	4	0.333	0.330	4	0.255	0.250	4
2018	0.278	0.275	4	0.510	0.495	4	0.278	0.270	4	0.320	0.290	4
1990-1999	0.321	0.256	56	0.433	0.380	56	0.473	0.289	12	0.383	0.282	57
2000-2018	0.340	0.240	92	0.546	0.453	92	0.464	0.396	25	0.370	0.300	91

Definition: -- No data

Annually, the lowest mean TP concentrations occurred in: 2002 for the Republican River near Hardy, NE (SC231), with a mean of 0.206 mg/L; 1995 for the Buffalo Creek near Concordia (SC509), with a mean of 0.296 mg/L; 2018 for the Wolf Creek near Concordia (SC707), with a mean of 0.278 mg/L; and 2002 for the Republican River near Rice (SC510), with a mean of

Figure 12. Total phosphorus by sampling date and annual mean and median total phosphorus for the Republican River near Hardy, NE (SC231).

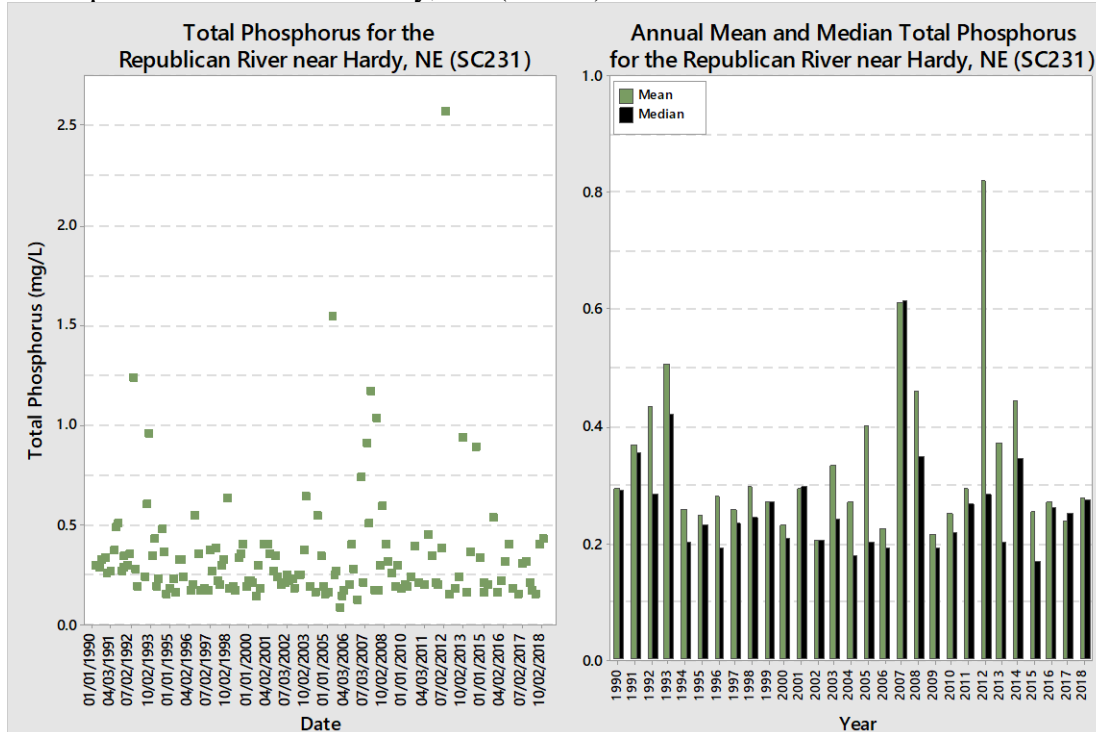


Figure 13. Total phosphorus by sampling date and annual mean and median total phosphorus for the Buffalo Creek near Concordia (SC509).

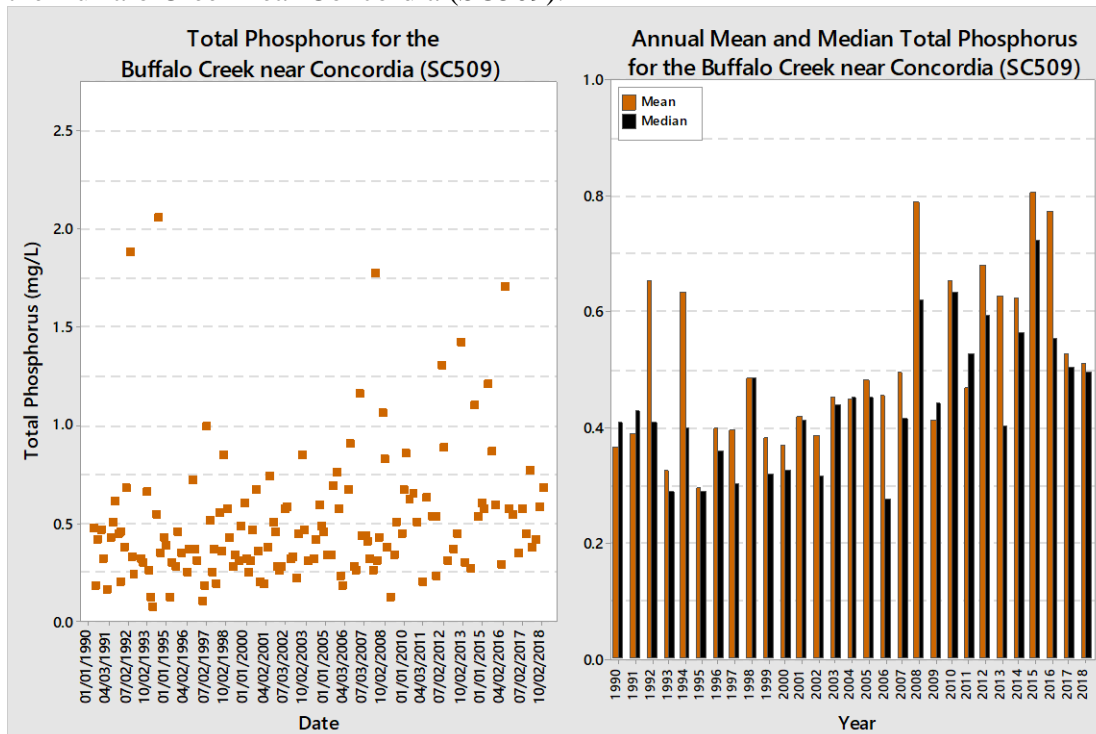


Figure 14. Total phosphorus by sampling date and annual mean and median total phosphorus for the Wolf Creek near Concordia (SC707).

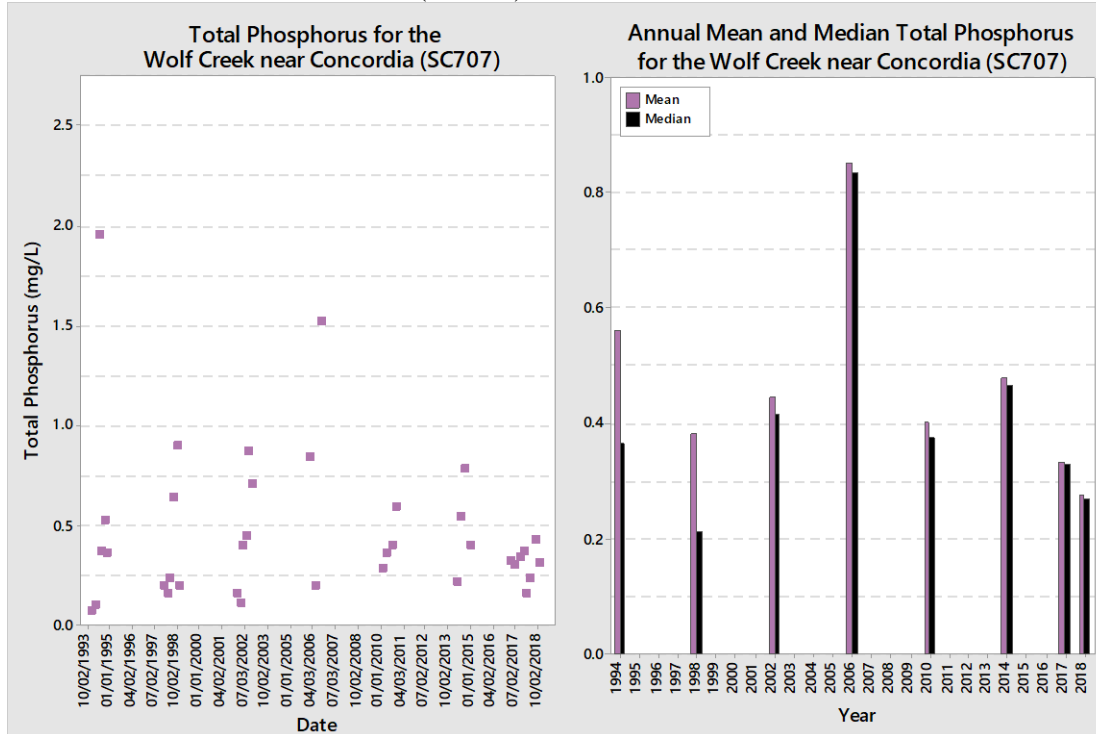
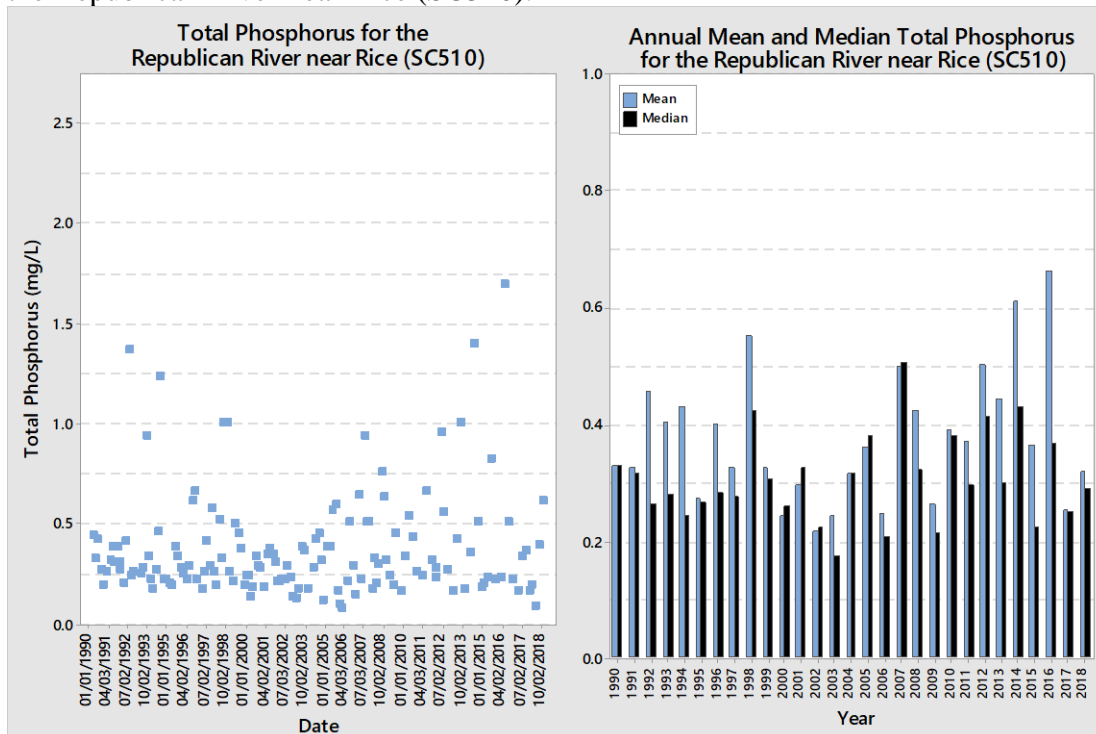


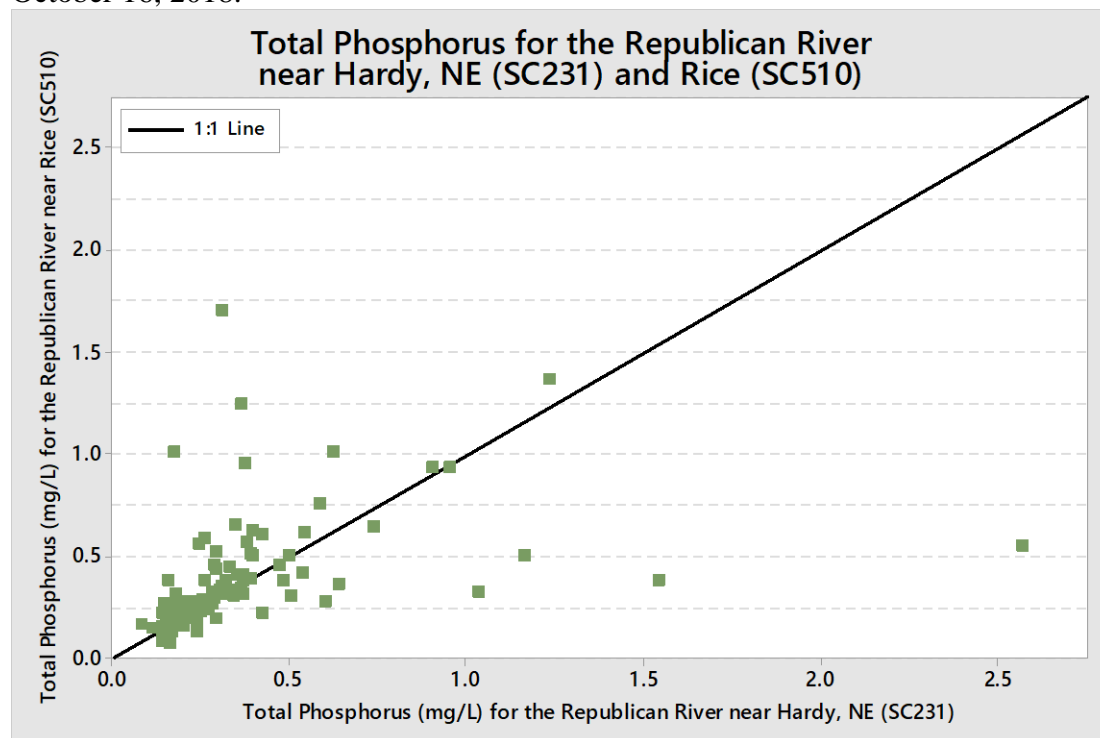
Figure 15. Total phosphorus by sampling date and annual mean and median total phosphorus for the Republican River near Rice (SC510).



0.217 mg/L. The lowest median TP concentrations occurred in: 2015 for the Republican River near Hardy, NE (SC231), with a median of 0.170 mg/L; 2006 for the Buffalo Creek near Concordia (SC509), with a median of 0.278 mg/L; 1998 for the Wolf Creek near Concordia (SC707), with a median of 0.213 mg/L; and 2003 for the Republican River near Rice (SC510), with a median of 0.177 mg/L. The lowest mean and median TP concentrations in 2002 and 2006 correspond to lower annual flow years; meanwhile, the remaining annual lows correspond to higher annual flow years, with the only consistent trend at Wolf Creek near Concordia (SC707). This variability among annual flow conditions for high and low TP concentrations and among stations may be due to the various influences of nonpoint sources in these watersheds.

Individual TP samples collected on concurrent days are also highly variable when comparing upstream and downstream samples. Samples collected for the Republican River near Hardy, NE (SC231) and downstream Republican River near Rice (SC510) indicate that TP sources within these watersheds can vary considerably, though the highest concentration originates upstream of the Republican River near Hardy, NE (SC231; **Figure 16**).

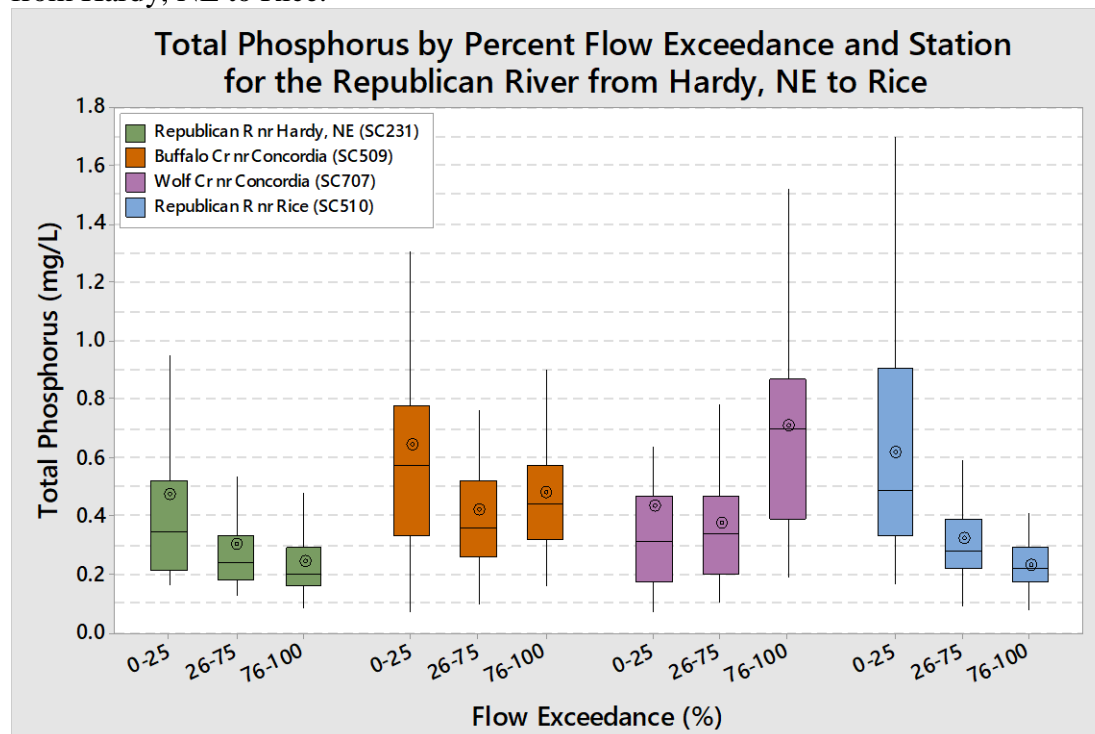
Figure 16. Total phosphorus at upstream Republican River near Hardy, NE (SC231) versus downstream Republican River near Rice (SC510) for concurrent day samples, March 13, 1990 to October 16, 2018.



Flow condition variability, including critical low flow conditions, are accounted for in this TMDL. Total phosphorus concentrations for the main stem Republican River near Hardy, NE (SC231) and Rice (SC510) are highest during high flow conditions (0 to 25%; **Figure 17**). Both stations exhibit a decline in TP concentrations as flow conditions decrease to normal (26 to 75%) and low (76 to 100%) flow conditions. For example, the Republican River near Rice (SC510) has mean and median TP concentrations of 0.614 and 0.490 mg/L, respectively, during high flow

conditions (**Table 8**). These concentrations are approximately two to three times lower during low flow conditions, declining to a mean and median of 0.232 and 0.216 mg/L, respectively. Higher TP concentrations during high flow conditions, such as those seen at the Republican River near Hardy, NE (SC231) and Rice (SC510), can be indicative of watersheds with a more dominant nonpoint source influence.

Figure 17. Total phosphorus by percent flow exceedance and station for the Republican River from Hardy, NE to Rice.



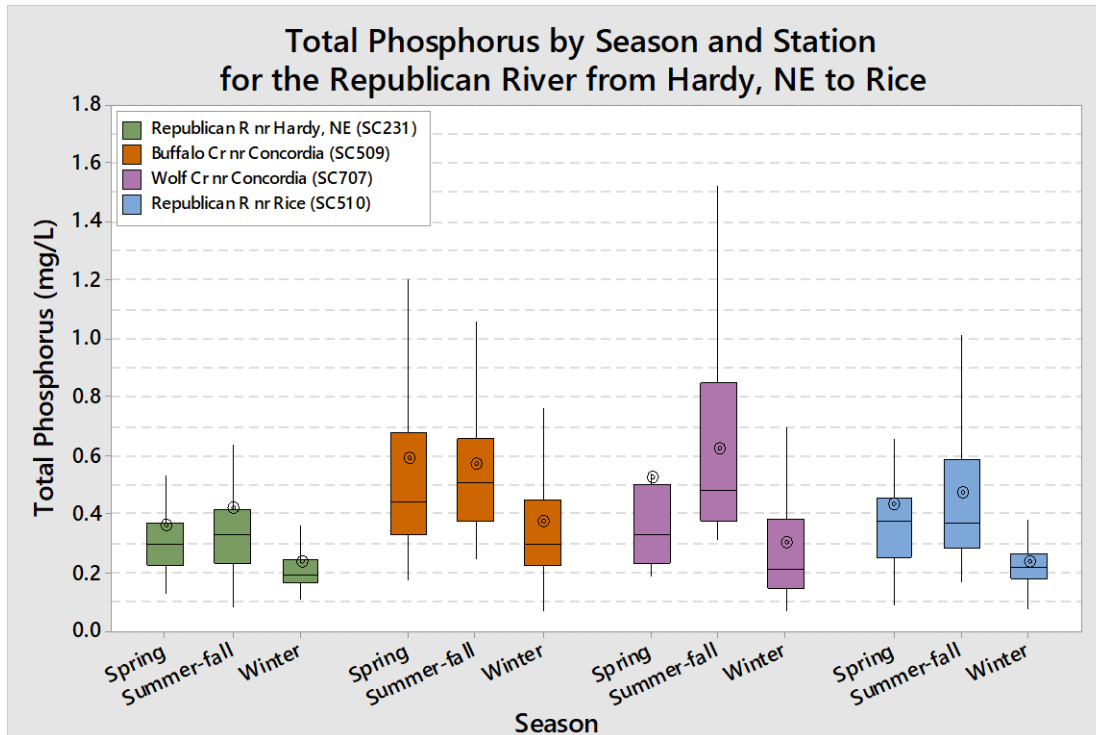
While Buffalo Creek near Concordia (SC509) also exhibits higher TP concentrations during high flow conditions, TP concentrations at this station do not continue to decline during low flow conditions. Instead, TP concentrations during low flow conditions increase above concentrations seen at normal flow conditions. Of the four stations, Wolf Creek near Concordia (SC707) deviates most notably from the previously discussed patterns, with the highest TP concentrations occurring during low flow conditions. At low flow conditions, Wolf Creek near Concordia (SC707) TP concentrations are nearly two times TP concentrations at high flow conditions. Increases in TP concentrations at low flow conditions, such as those seen at Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707), are indicative of nonpoint source TP loading, as well.

Table 8. Total phosphorus concentration mean, median, and number of samples (N) by season (spring: April through June, summer-fall: July through October, winter: November through March), flow range, and station for the Republican River from Hardy, NE to Rice.

Flow Exceedance (%)	Spring			Summer-Fall			Winter			All		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Total Phosphorus (mg/L) for Republican R nr Hardy, NE (SC231)												
0-25	0.373	0.350	13	0.840	0.604	12	0.260	0.203	15	0.471	0.344	40
26-75	0.376	0.280	19	0.324	0.330	23	0.238	0.200	31	0.301	0.238	73
76-100	0.290	0.242	7	0.255	0.223	17	0.192	0.162	11	0.242	0.202	35
0-100	0.359	0.300	39	0.421	0.331	52	0.235	0.195	57	0.333	0.253	148
Total Phosphorus (mg/L) for Buffalo Cr nr Concordia (SC509)												
0-25	0.687	0.501	18	0.696	0.645	13	0.500	0.480	10	0.644	0.570	41
26-75	0.459	0.425	16	0.547	0.519	18	0.341	0.274	35	0.422	0.359	69
76-100	0.679	0.500	5	0.504	0.460	21	0.354	0.340	12	0.479	0.440	38
0-100	0.592	0.439	39	0.567	0.506	52	0.371	0.301	57	0.498	0.422	148
Total Phosphorus (mg/L) for Wolf Cr nr Concordia (SC707)												
0-25	0.770	0.450	4	0.427	0.380	4	0.159	0.150	5	0.429	0.310	13
26-75	0.265	0.265	2	0.591	0.520	5	0.283	0.265	10	0.372	0.340	17
76-100	0.289	0.289	2	0.945	0.870	3	0.767	0.767	2	0.707	0.700	7
0-100	0.524	0.330	8	0.625	0.482	12	0.303	0.210	17	0.455	0.360	37
Total Phosphorus (mg/L) for Republican R nr Rice (SC510)												
0-25	0.669	0.460	13	0.742	0.657	15	0.283	0.254	8	0.614	0.490	36
26-75	0.348	0.365	18	0.415	0.370	23	0.246	0.227	36	0.321	0.280	77
76-100	0.245	0.219	8	0.271	0.278	14	0.180	0.174	13	0.232	0.216	35
0-100	0.434	0.377	39	0.471	0.369	52	0.236	0.220	57	0.371	0.287	148

Seasonal variability is accounted for in this TMDL. Seasonally, spring and summer-fall have greater TP means and medians than winter for all stations (**Table 8; Figure 18**). Among the seasons, all stations typically have the highest TP means and medians in summer-fall; the exceptions to this are Buffalo Creek near Concordia (SC509), which has a similar TP mean in spring (0.592 mg/L) and summer-fall (0.567 mg/L), and Republican River near Rice (SC510), which has a similar TP median in spring (0.377 mg/L) and summer-fall (0.369 mg/L). High TP concentrations in summer-fall, as seen at the stations, may indicate watersheds with more nonpoint source TP influences.

Figure 18. Total phosphorus by season and station for the Republican River from Hardy, NE to Rice.



The influence of nonpoint sources for the Republican River from Hardy, NE to Rice are also evident in individual stream samples through the variability in TP concentration magnitude and seasonal distribution across the range of percent flow exceedances (**Figures 19-22**). The stations Republican River near Hardy, NE (SC231) and Rice (SC510) each display a trend of decreasing TP concentrations as flow decreases (**Figures 19 and 22**). The majority of TP concentrations above 0.75 mg/L occur in spring and summer-fall during flow conditions greater than 30% flow exceedance, likely corresponding to runoff due to precipitation. The stations Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707) each display a trend of high TP concentrations during high and low flow conditions (**Figures 20 and 21**). The majority of TP concentrations above 0.75 mg/L occur in spring and summer-fall for both high and low flow conditions at these stations. As with the main stem stations, high TP concentrations during high flow conditions likely correspond to runoff due to precipitation; high TP concentrations during low flow conditions, however, are contributed by various sources.

Figure 19. Total phosphorus by percent flow exceedance and season for the Republican River near Hardy, NE (SC231).

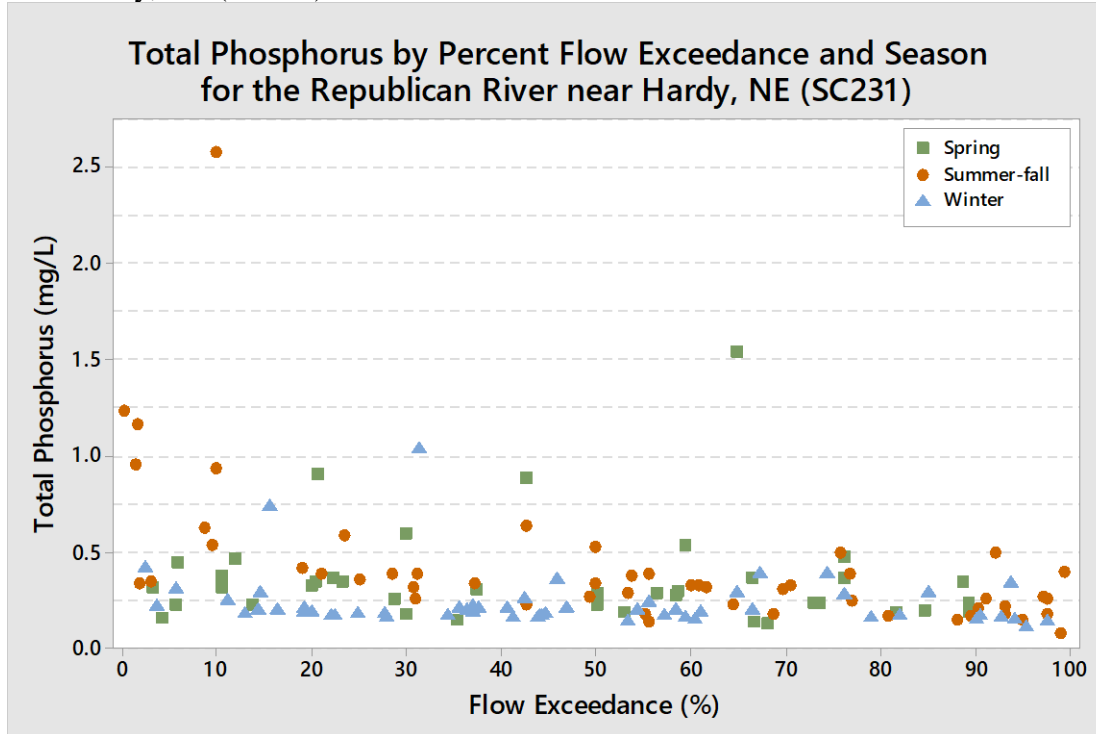


Figure 20. Total phosphorus by percent flow exceedance and season for the Buffalo Creek near Concordia (SC509).

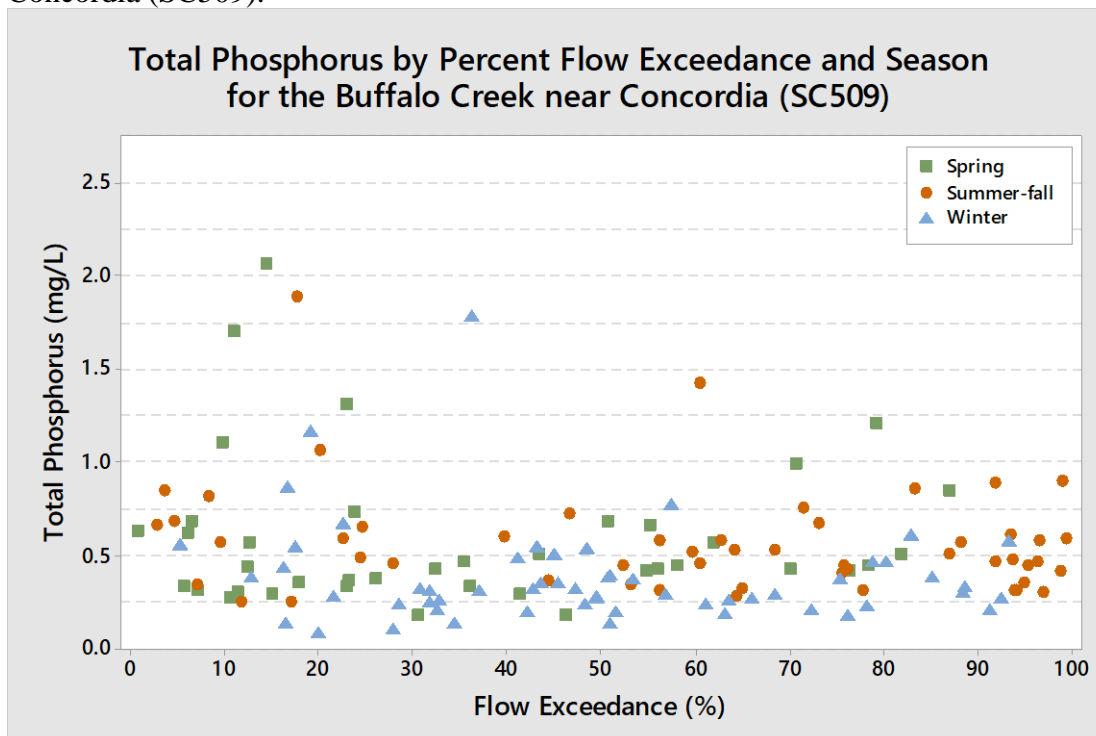


Figure 21. Total phosphorus by percent flow exceedance and season for the Wolf Creek near Concordia (SC707).

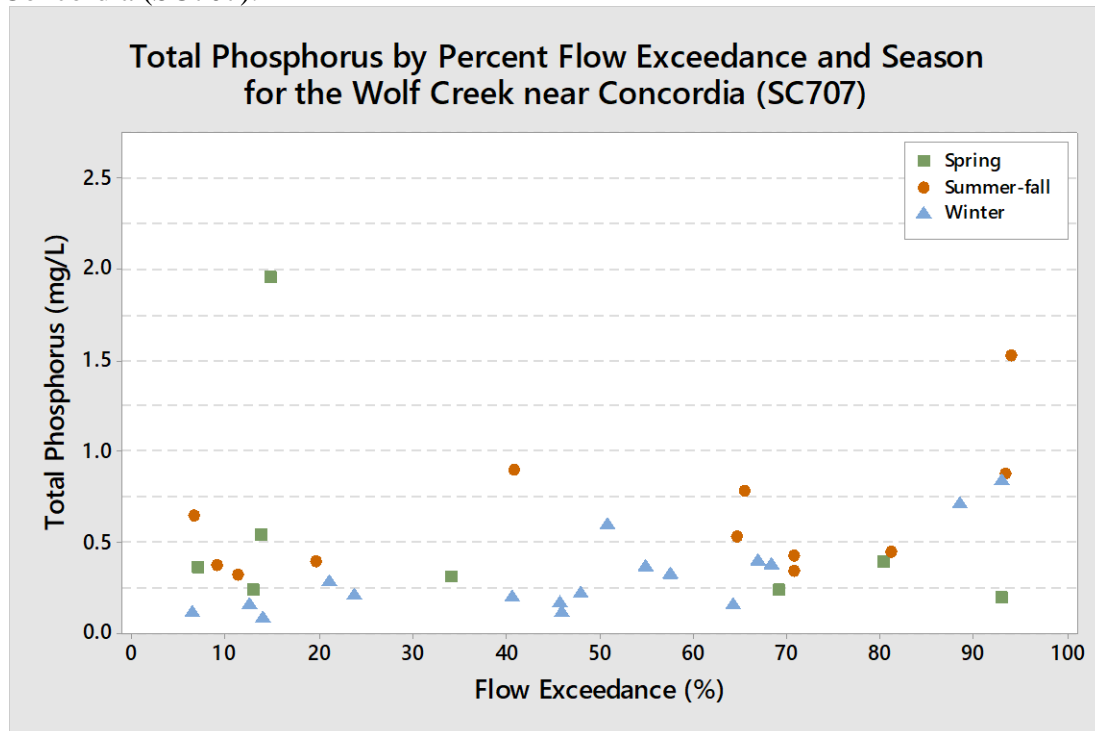
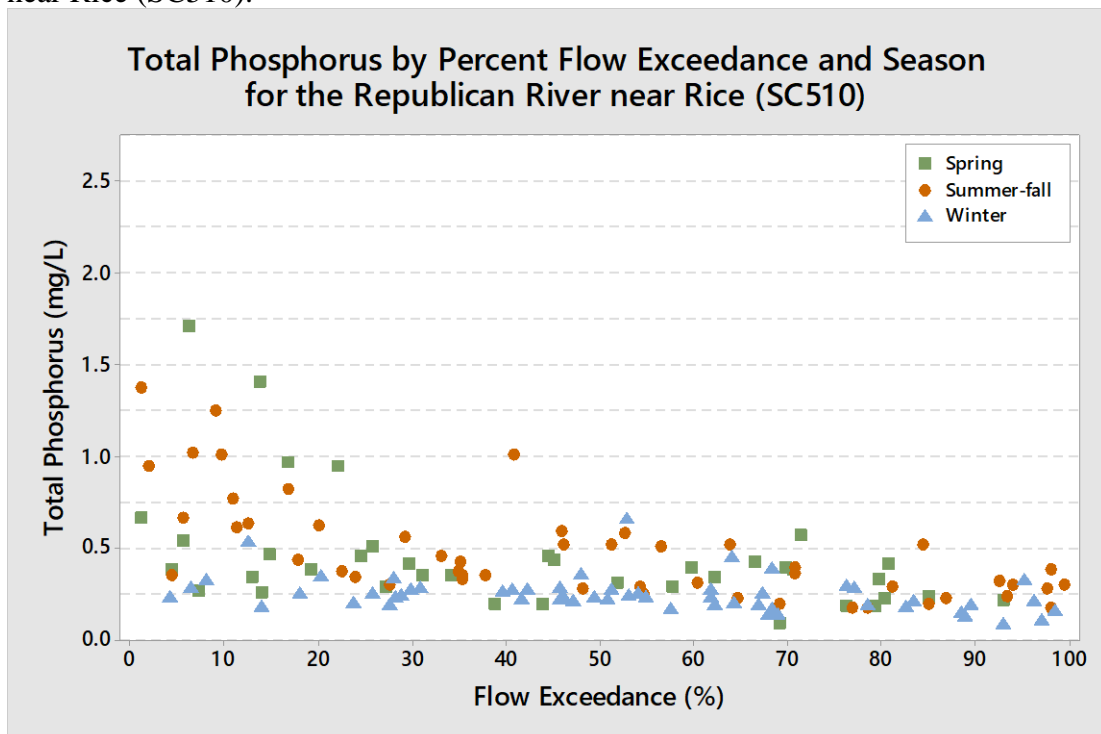


Figure 22. Total phosphorus by percent flow exceedance and season for the Republican River near Rice (SC510).



Total Phosphorus and Other Water Quality Parameters

Total phosphorus has well-established and defined relationships with orthophosphate (OP) and total suspended solids (TSS). These relationships are examined further in order to delineate potential sources of TP loading to the Republican River from Hardy, NE to Rice.

Orthophosphate

The soluble portion of TP that is readily available for biological use is OP. It is commonly found in higher concentrations in effluent, such as the discharge of municipal WWTFs, or more diffusely in runoff from livestock sources. Only samples measuring above the reporting limit are included in the analysis presented, resulting in a left censored data set which may overestimate true OP concentration means (**Table 9**). In addition, reporting limits for OP have changed throughout the period of record: 0.01 mg/L from 1995-1996, 0.02 mg/L from 1997 to February 2002, and 0.25 mg/L from March 2002 to 2018.

Table 9. Mean of detected orthophosphate (OP) samples, mean ratio of OP and total phosphorous (TP), sample number (N), and percentage of samples greater than the analytical reporting limit (> RL) separated by reporting limit increases for the Republican River from Hardy, NE to Rice, February 13, 1995 to October 16, 2018.

Station	Sample Information	Orthophosphate Period of Record			
		1995-1996 (0.01 mg/L)	1997-Feb. 2002 (0.02 mg/L)	Mar. 2002-2018 (0.25 mg/L)	1995-2018
Republican R nr Hardy, NE (SC231)	Mean (mg/L)	0.14	0.12	0.44	0.29
	N	9	5	14	28
	Sample Percent > RL (%)	80	35	19	27
	Mean Ratio OP:TP	0.53	0.43	0.66	0.57
Buffalo Cr nr Concordia (SC509)	Mean (mg/L)	0.17	0.14	0.43	0.33
	N	8	9	34	51
	Sample Percent > RL (%)	80	53	44	49
	Mean Ratio OP:TP	0.45	0.27	0.61	0.52
Wolf Cr nr Concordia (SC707)	Mean (mg/L)	–	–	0.41	0.37
	N	–	1	9	10
	Sample Percent > RL (%)	–	100	41	43
	Mean Ratio OP:TP	–	–	0.731	0.670
Republican R nr Rice (SC510)	Mean (mg/L)	0.11	0.12	0.36	0.25
	N	10	5	17	32
	Sample Percent > RL (%)	91	29	23	31
	Mean Ratio OP:TP	0.42	0.47	0.53	0.49

Definition: – - No data

Orthophosphate is detected throughout the period of record at all stations, with OP concentrations consistently exceeding the reporting limit of 0.25 mg/L after 2002 (**Figure 23**). The Republican River near Hardy, NE (SC231) and Buffalo Creek near Concordia (SC509) both have the highest OP concentration of 0.73 mg/L in August 2013. The Buffalo Creek near Concordia (SC509) and Wolf Creek near Concordia (SC707) have consistently maintained the highest percentage of OP samples detected above the reporting limit (49 and 43%, respectively). Both stations also have the highest censored mean OP concentrations throughout the overall period of record, with OP concentrations of 0.33 and 0.37 mg/L, respectively. Both of these stations are predominantly influenced by nonpoint sources. The wide range of scatter without seasonal or low flow trends indicates that diffuse sources of OP are more prevalent in these watersheds (**Figure 24**).

Figure 23. Orthophosphate samples measuring greater than the reporting limit by station for the Republican River from Hardy, NE to Rice, February 13, 1995 to October 16, 2018.

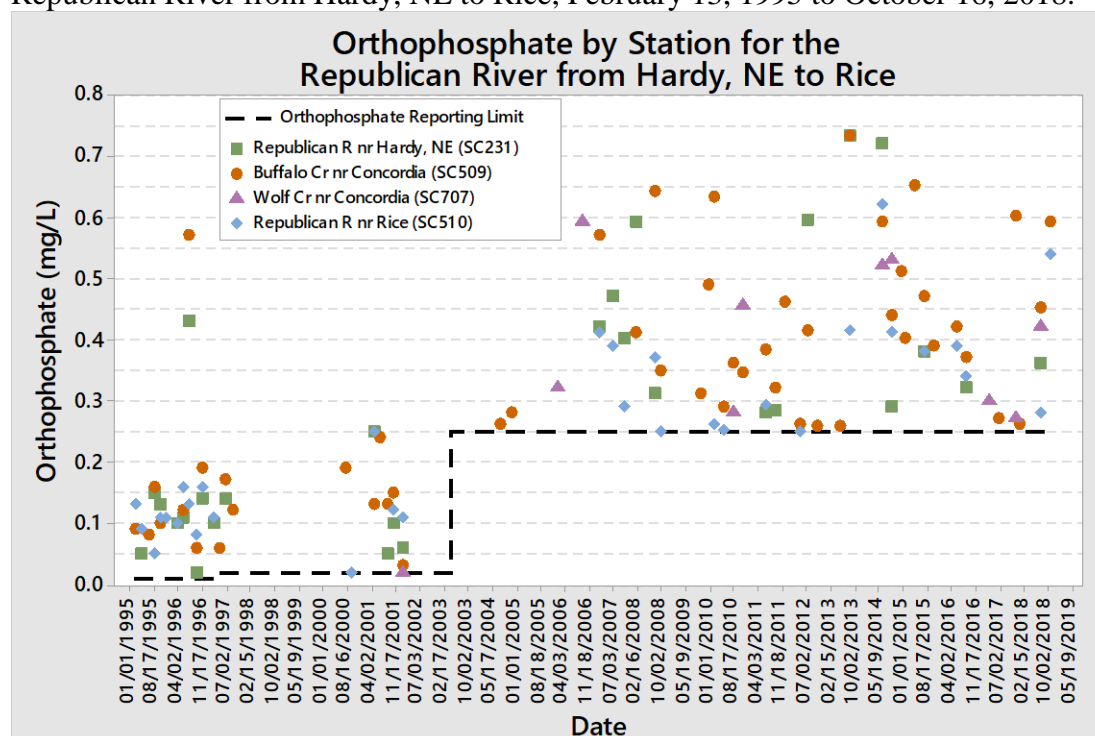
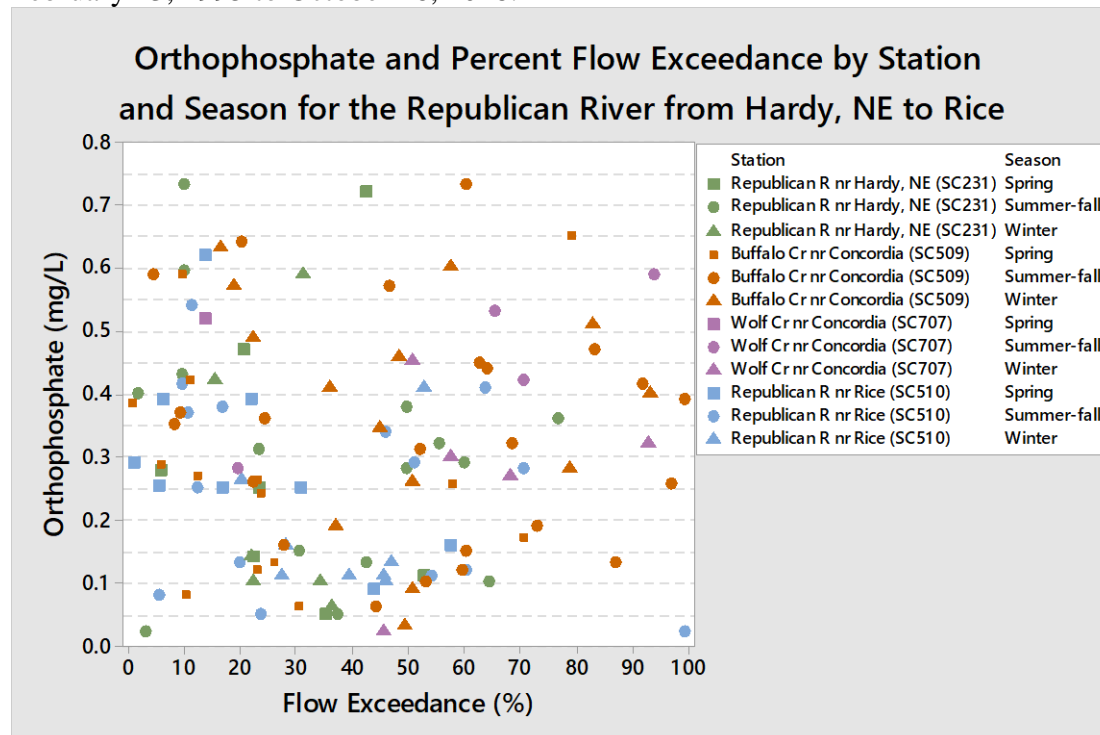


Figure 24. Orthophosphate samples measuring greater than the reporting limit versus percent flow exceedance by station and season for the Republican River from Hardy, NE to Rice, February 13, 1995 to October 16, 2018.



Total Suspended Solids

Phosphorus has a high affinity for fixation in soils, where it is adsorbed from soil solution. Erosion of phosphorus-laden soil particles is a common means for phosphorus to enter streams, where it is then desorbed. This natural propensity for adsorption and desorption to soil particles creates a positively correlated relationship between TP and TSS that is evident at all stations in the watershed (**Figures 25-28**). All stations display a correlation value greater than 0.40 except for Wolf Creek near Concordia (SC707), which may be due to the more limited data set currently available at this station. Furthermore, the relationship between TP and TSS remains well-defined during all flow conditions for all four stations. These well-defined relationships between TP and TSS indicate that nonpoint sources of TP are more influential in these watersheds.

Figure 25. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids by percent flow exceedance for the Republican River near Hardy, NE (SC231).

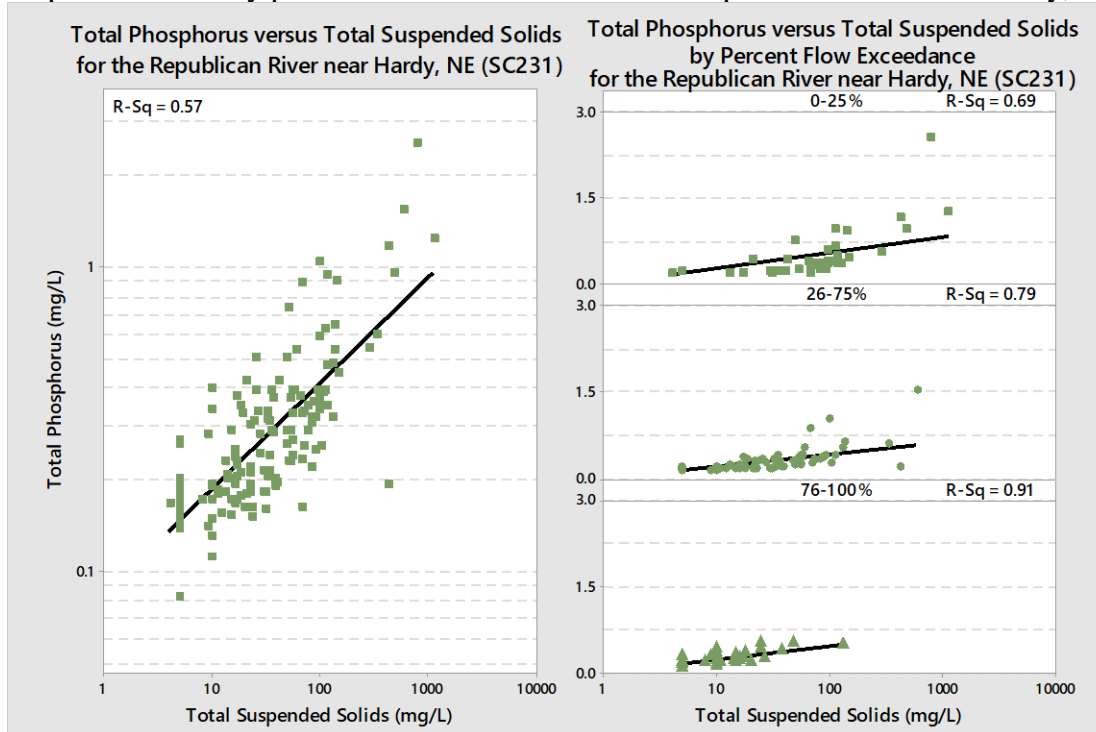


Figure 26. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids by percent flow exceedance for the Buffalo Creek near Concordia (SC509).

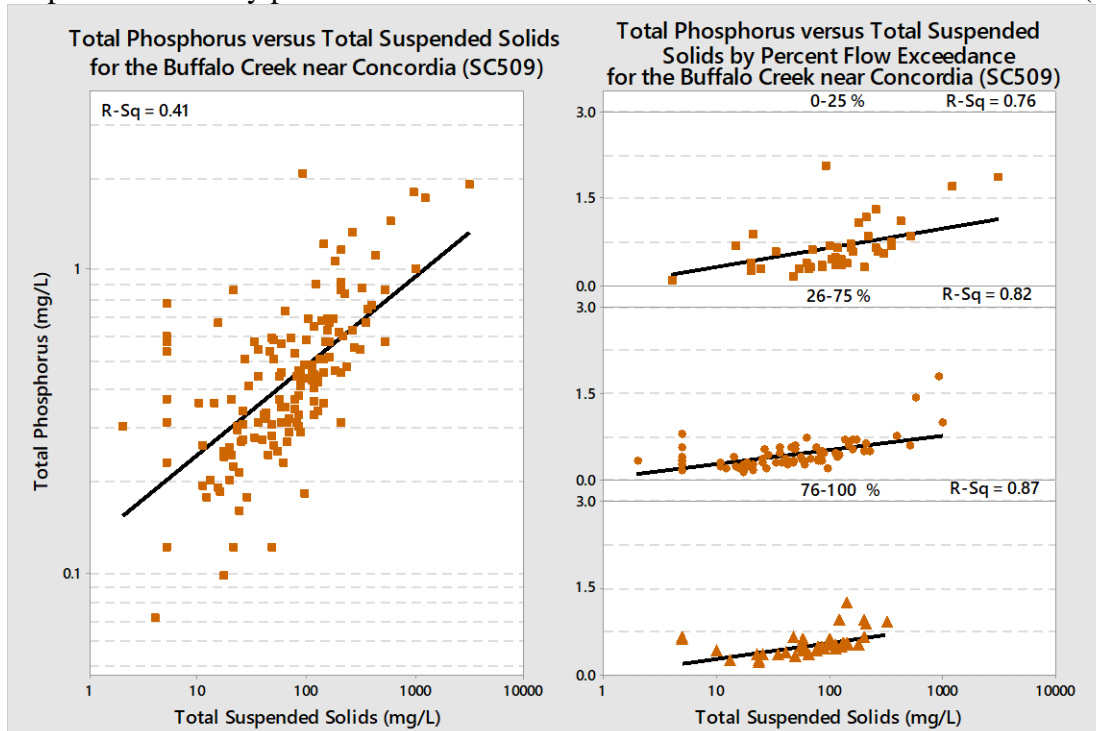


Figure 27. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids by percent flow exceedance for the Wolf Creek near Concordia (SC707).

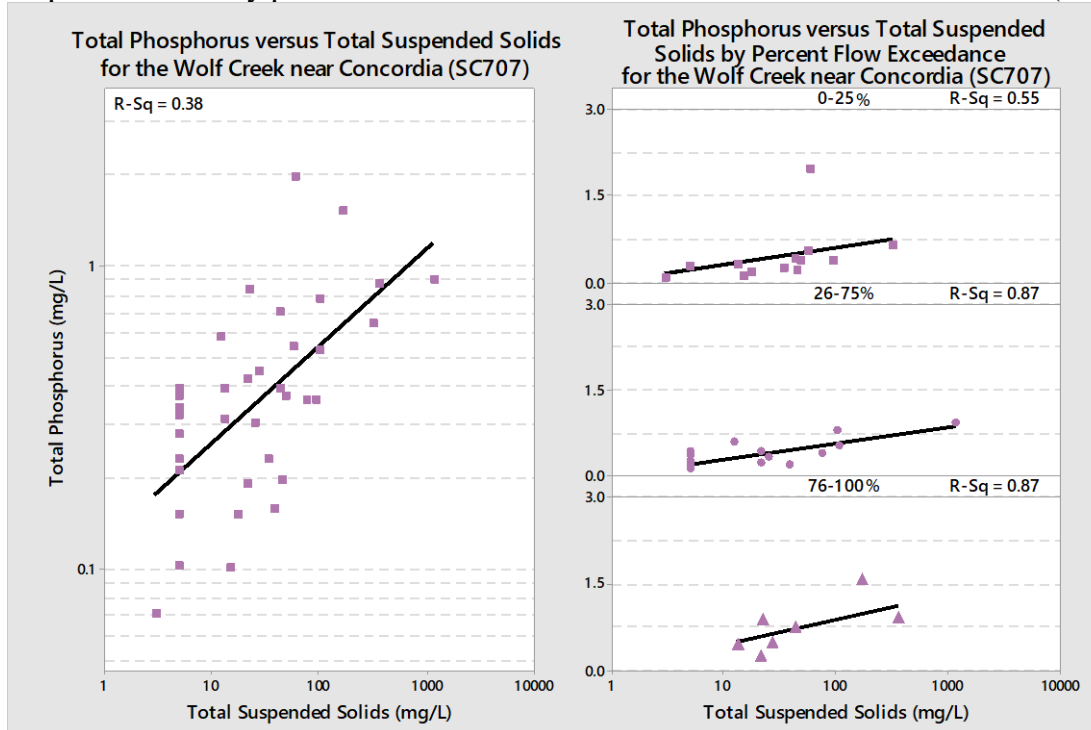
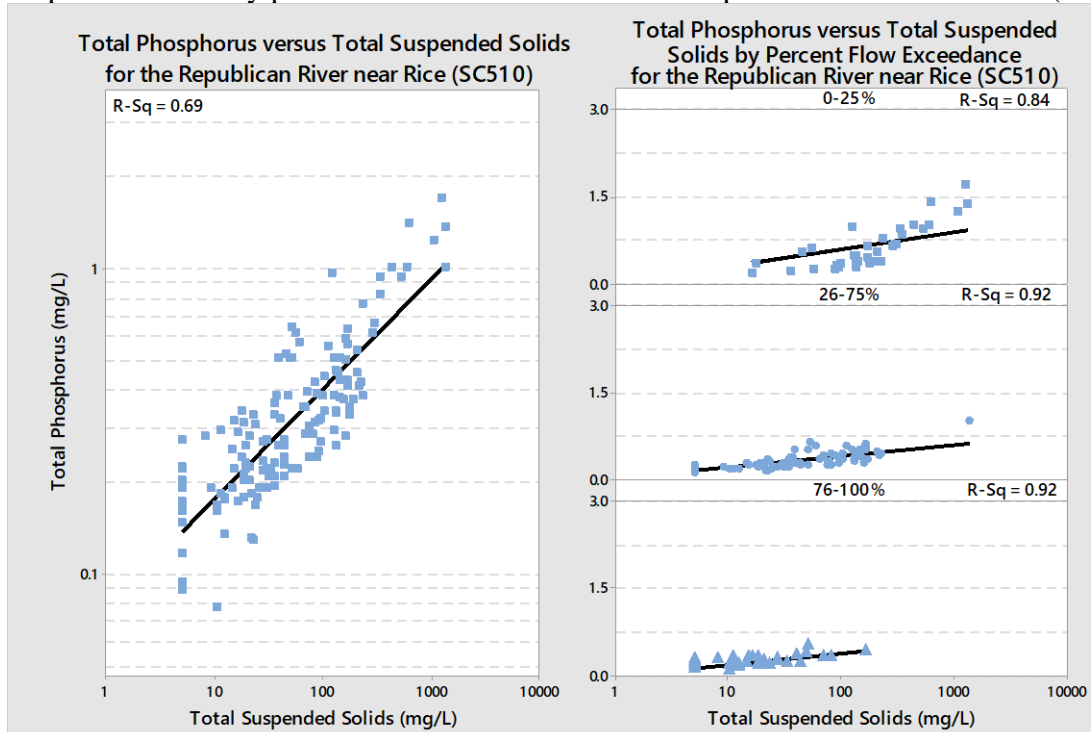


Figure 28. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids by percent flow exceedance for the Republican River near Rice (SC510).



Total Phosphorus and Biological Indicators

The narrative criteria of the Kansas Surface Water Quality Standards are based on conditions of the prevailing biological community. Excessive primary productivity may be indicated by extreme shifts in dissolved oxygen (DO), dissolved oxygen saturation (DO saturation), and pH as the chemical reactions of photosynthesis and respiration alter the ambient levels of oxygen and acid-base balance of the stream. These shifts, in turn, can result in undesirable regime shifts in the algal biomass and biological community within the stream.

Dissolved Oxygen

At all sites for the watershed, dissolved oxygen and temperature are inversely related (**Figures 29-32**). This corresponds to seasonal changes in DO and temperature, where low mean DO concentrations occur in spring and summer-fall when temperatures are highest, and high mean DO concentrations occur in winter when temperatures are lowest (**Table 10**). This relationship is expected because oxygen becomes less soluble in water as temperatures increase. Additionally, DO exhibits a diel trend due to daily fluctuations in photosynthetic activity. The presented data captures this daily variability based upon whether a sample was collected in the morning (7:28 to 12:00), afternoon (12:02 to 17:54), or evening (18:15 to 19:40; **Table 11**); morning and evening samples tend to have lower DO concentrations and afternoon samples tend to have higher DO concentrations.

Figure 29. Dissolved oxygen and the relationship between dissolved oxygen and temperature for the Republican River near Hardy, NE (SC231).

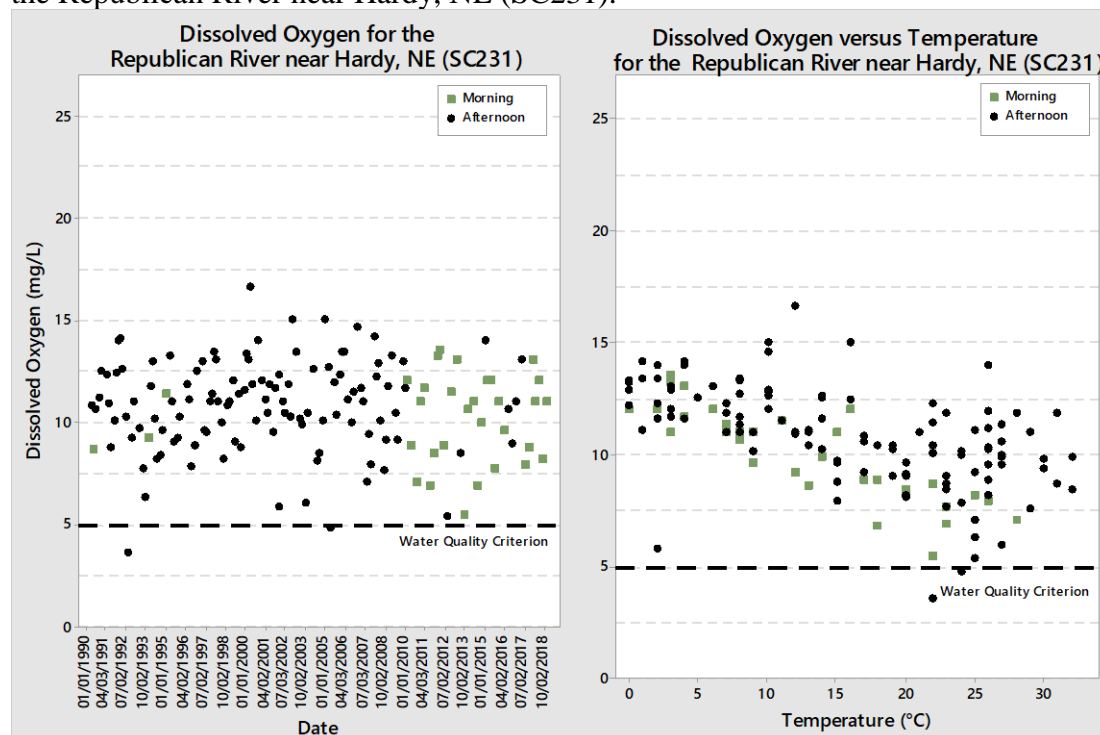


Figure 30. Dissolved oxygen and the relationship between dissolved oxygen and temperature for the Buffalo Creek near Concordia (SC509).

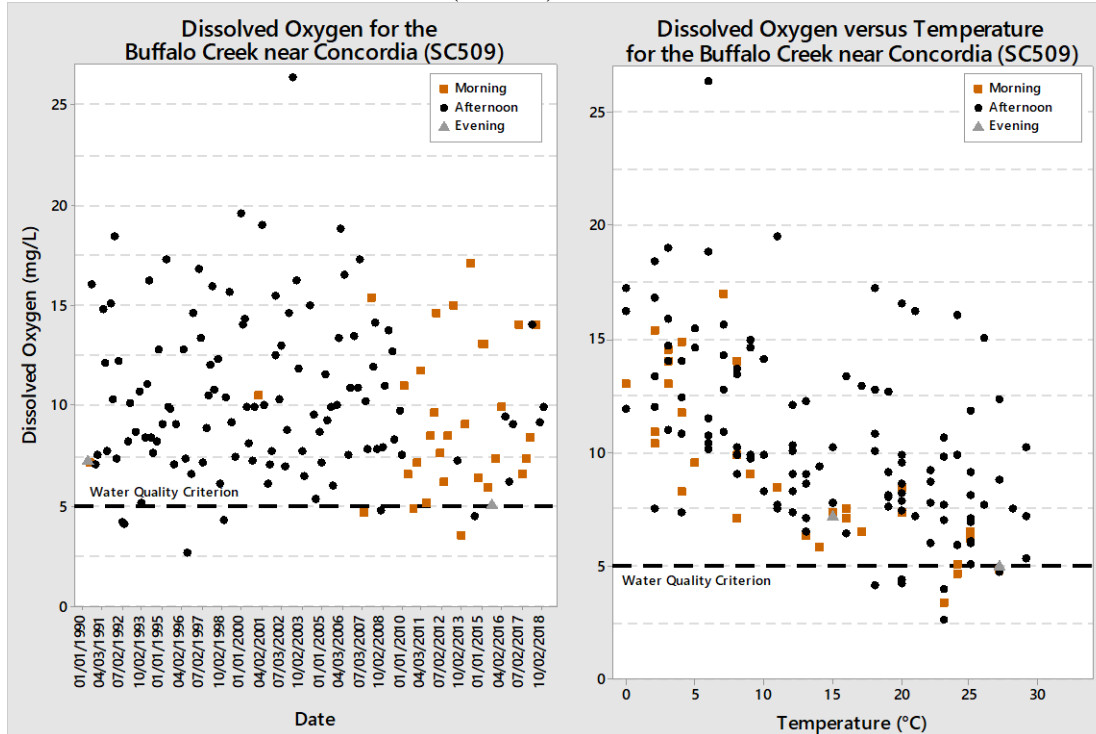


Figure 31. Dissolved oxygen and the relationship between dissolved oxygen and temperature for the Wolf Creek near Concordia (SC707).

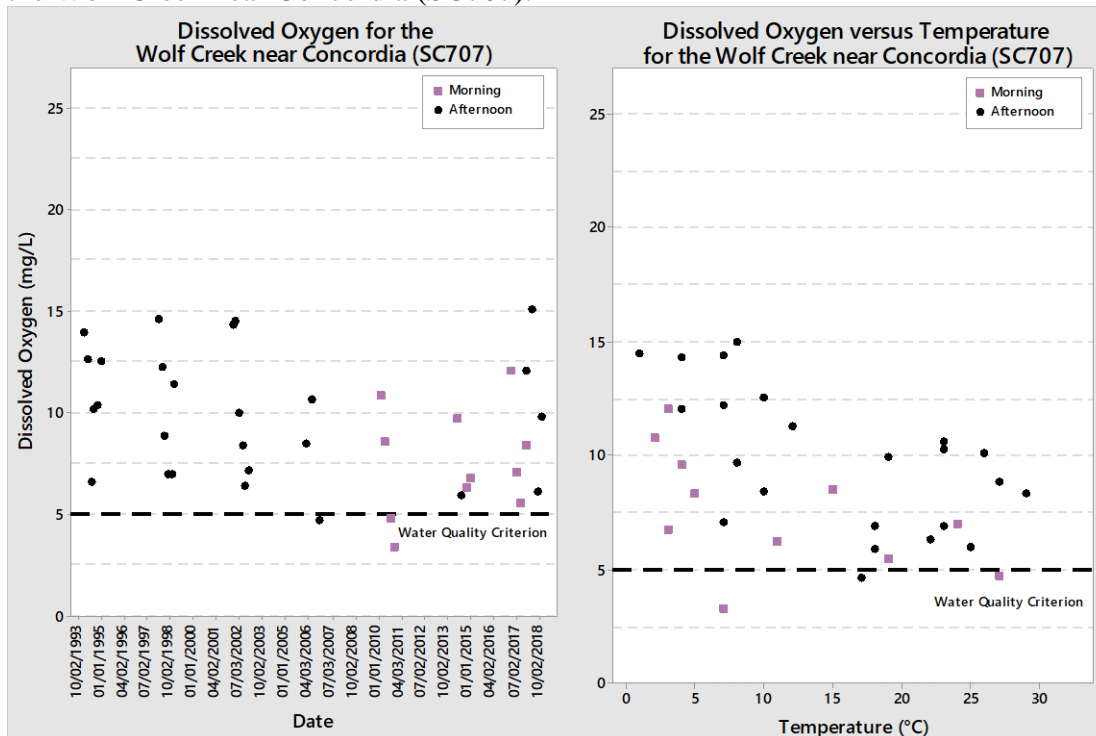
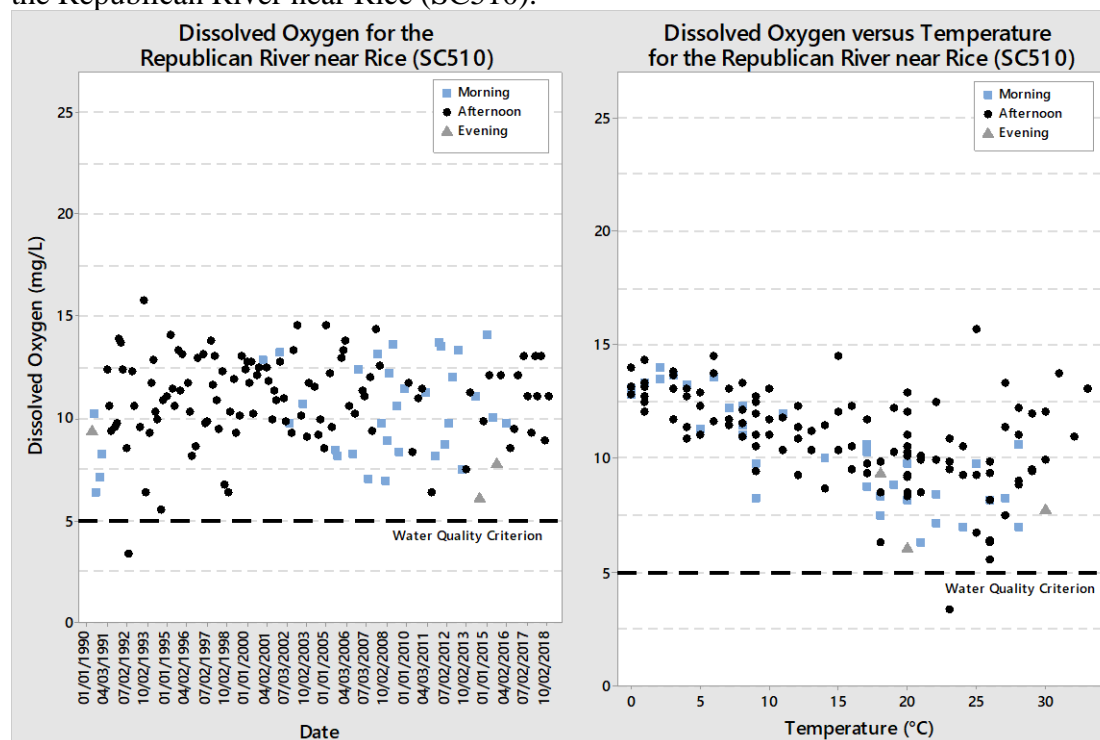


Figure 32. Dissolved oxygen and the relationship between dissolved oxygen and temperature for the Republican River near Rice (SC510).



All stations within the watershed have a DO excursion below the water quality criterion of 5.0 mg/L: Republican River near Hardy, NE (SC231) has excursions of 3.6 and 4.8 mg/L in July 1992 and April 2005, respectively; Buffalo Creek near Concordia (SC509) has nine excursions ranging from 2.6 to 4.8 mg/L from May 1992 to July 2014; Wolf Creek near Concordia (SC707) has excursions of 4.6, 4.7, and 3.3 mg/L in September 2006, August 2010, and November 2010, respectively; and Republican River near Rice (SC510) has an excursion of 3.3 mg/L in July 1992.

Table 10. Mean temperature, dissolved oxygen, and dissolved oxygen saturation, as well as median pH, by season for the Republican River from Hardy, NE to Rice.

Station	Spring	Summer-Fall	Winter	All Seasons
Temperature (°C)				
Republican R nr Hardy, NE (SC231)	20	22	5.9	15
Buffalo Cr nr Concordia (SC509)	19	21	5.5	14
Wolf Cr nr Concordia (SC707)	19	21	5.7	14
Republican R nr Rice (SC510)	20	22	6.0	15
Dissolved Oxygen (mg/L)				
Republican R nr Hardy, NE (SC231)	9.6	9.5	12	11
Buffalo Cr nr Concordia (SC509)	9.3	8.0	13	10
Wolf Cr nr Concordia (SC707)	9.0	7.1	11	9.2
Republican R nr Rice (SC510)	9.8	9.6	12	11

Station	Spring	Summer-Fall	Winter	All Seasons
Dissolved Oxygen Saturation (%)				
Republican R nr Hardy, NE (SC231)	106	107	99	104
Buffalo Cr nr Concordia (SC509)	99	87	100	96
Wolf Cr nr Concordia (SC707)	93	79	84	85
Republican R nr Rice (SC510)	107	110	98	105
pH				
Republican R nr Hardy, NE (SC231)	8.2	8.2	8.2	8.2
Buffalo Cr nr Concordia (SC509)	8.0	7.9	7.9	7.9
Wolf Cr nr Concordia (SC707)	8.0	7.7	7.7	7.8
Republican R nr Rice (SC510)	8.4	8.3	8.1	8.2

Table 11. Mean dissolved oxygen and dissolved oxygen saturation by diel variability for the Republican River from Hardy, NE to Rice.

Station	Dissolved Oxygen (mg/L) – Morning	Dissolved Oxygen (mg/L) – Afternoon	Dissolved Oxygen (mg/L) – Evening	Dissolved Oxygen Saturation (%) – Morning	Dissolved Oxygen Saturation (%) – Afternoon	Dissolved Oxygen Saturation (%) – Evening
Republican R nr Hardy, NE (SC231)	10	11	–	92	107	–
Buffalo Cr nr Concordia (SC509)	9.3	11	6.1	81	100	67
Wolf Cr nr Concordia (SC707)	7.5	10	–	66	93	–
Republican R nr Rice (SC510)	10	11	7.7	96	108	88

Definition: – - No data

Dissolved Oxygen Saturation

Primary productivity increases in the spring and summer-fall, when temperatures are higher and DO concentrations are lower. When primary productivity is excessive, oxygen from aquatic photosynthesis can create DO concentrations that exceed the natural oxygen equilibrium of the stream at a given temperature. The stream is considered supersaturated with oxygen when the expected oxygen capacity of the stream at a given temperature exceeds a DO saturation of 110%. Because of the system's diel characteristics, supersaturated conditions are more likely to be detected in the afternoon when photosynthesis and temperatures are at their peak.

All stations within the watershed display supersaturated conditions exceeding 110% DO saturation throughout the period of record, with the Republican River near Hardy, NE (SC231) and the Republican River near Rice (SC510) displaying the most distinct increases in DO saturation as temperature increases (**Figures 33-36**). However, excursions do occur throughout all temperature ranges at all stations. Notably, these excursions are dominated by samples collected in the afternoon. Overall, mean DO saturation samples at all stations do not exceed 110% and seasonal means are within the range of 79 to 110% throughout all seasons (**Table 10**). The stations with the most frequent high DO saturations are Republican River near Hardy, NE (SC231) and Republican River near Rice (SC510), which have the highest overall mean DO saturations of 104 and 105%, respectively.

Figure 33. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for the Republican River near Hardy, NE (SC231).

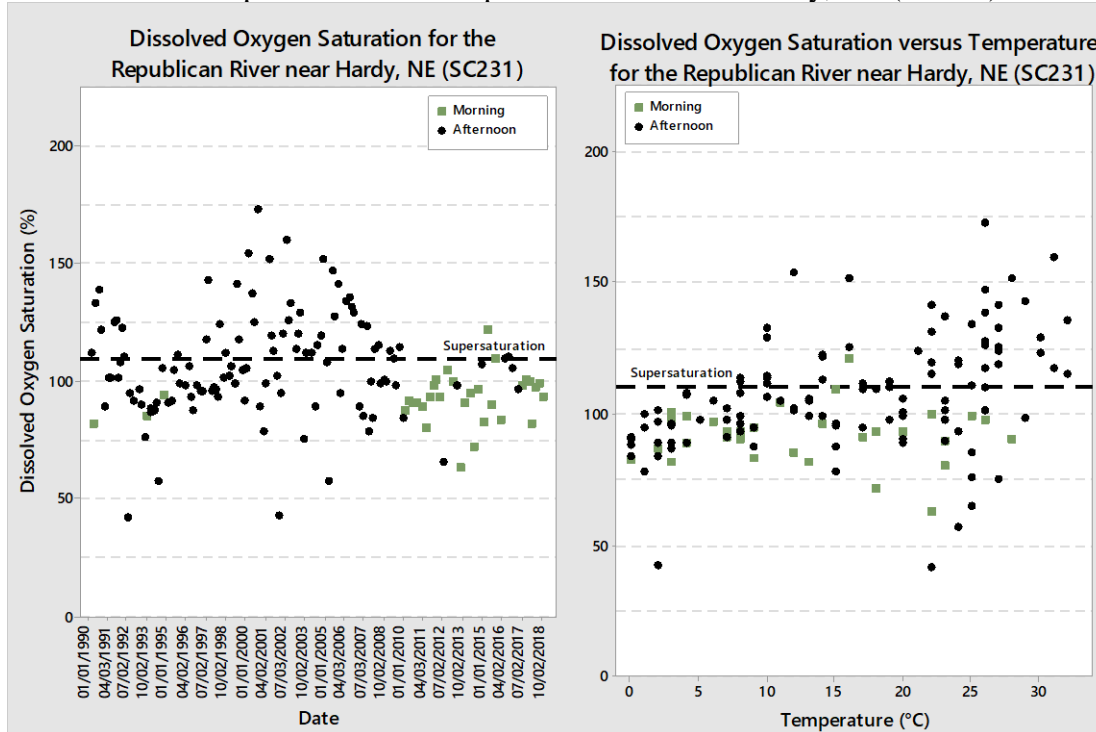


Figure 34. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for the Buffalo Creek near Concordia (SC509).

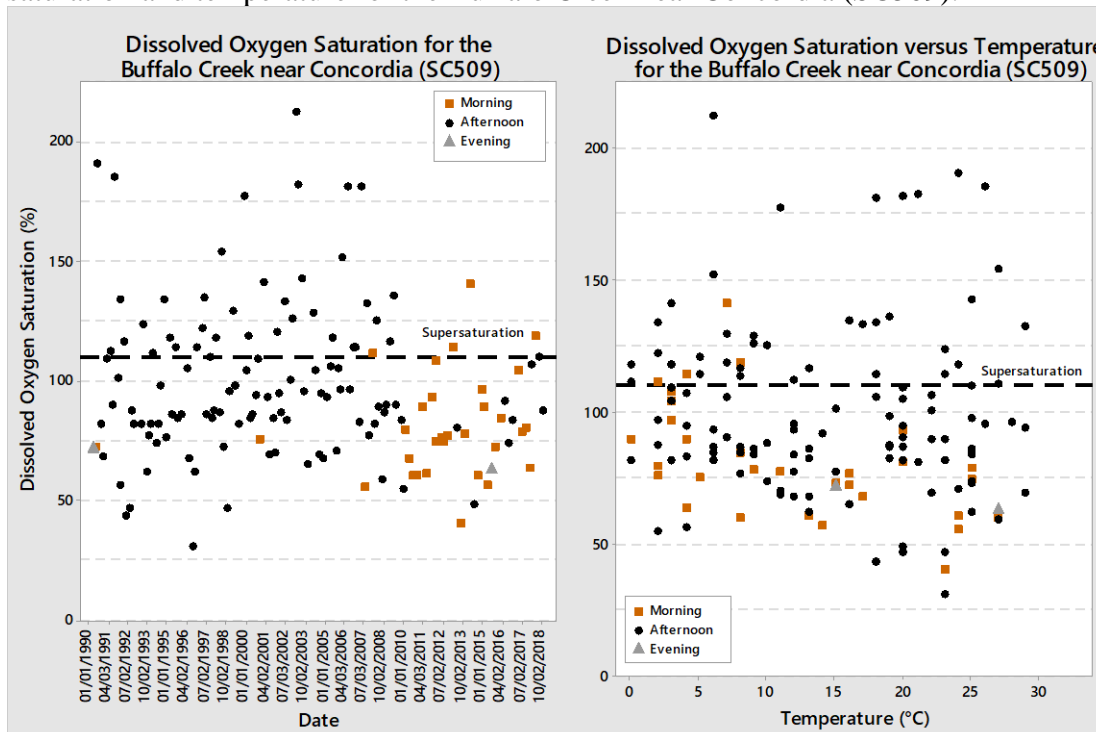


Figure 35. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for the Wolf Creek near Concordia (SC707).

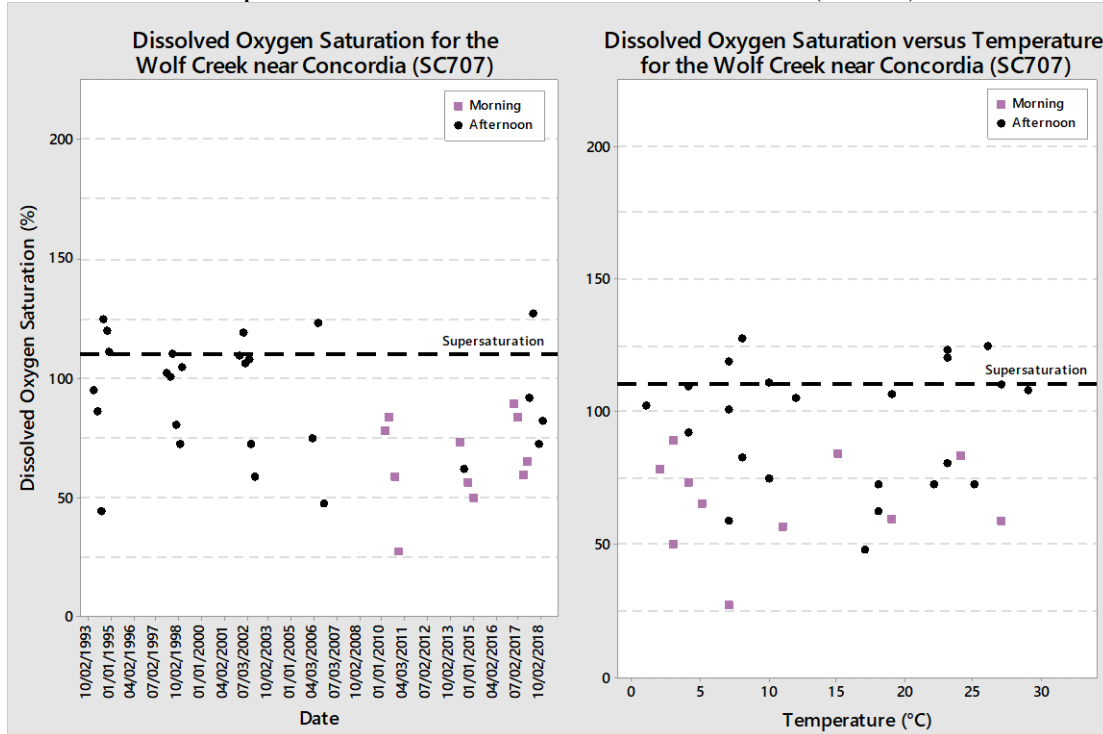
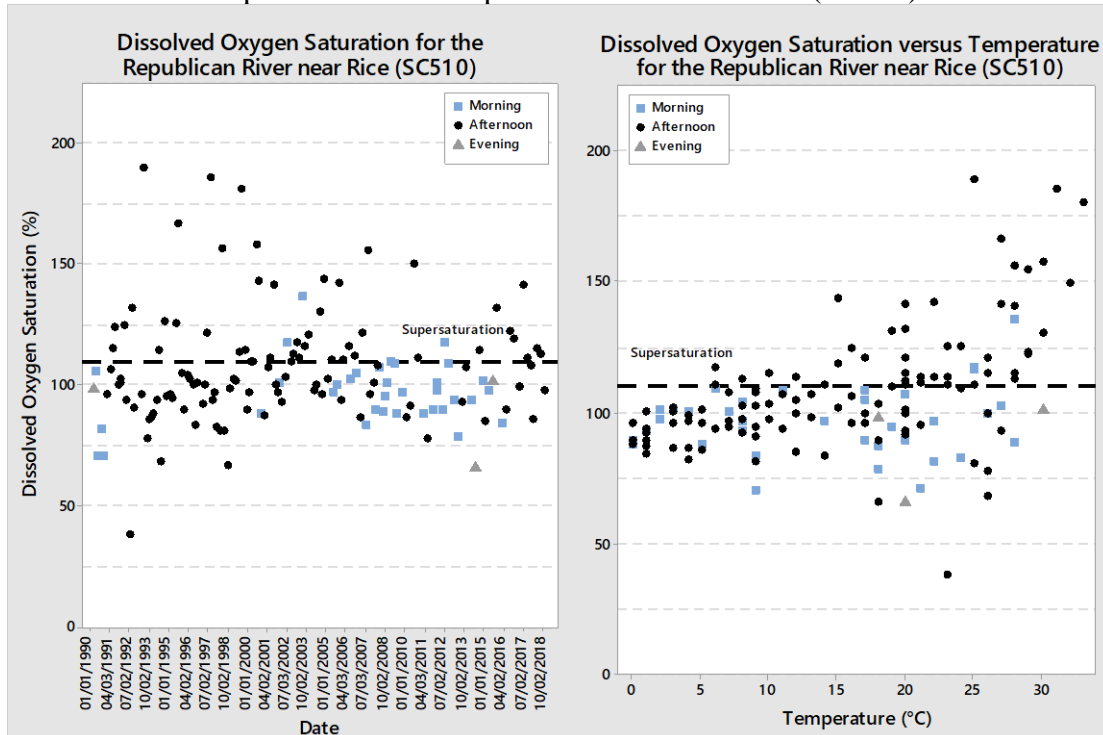


Figure 36. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for the Republican River near Rice (SC510).



pH

Another water quality indicator of primary productivity is pH, as photosynthesis can increase pH by removing carbon dioxide from the water. The numeric water quality criteria for pH is a range from 6.5 to 8.5. None of the stations in the watershed have pH values less than 6.5 (**Figures 37-40**), and Wolf Creek near Concordia (SC707) has never had an excursion greater than 8.5. The stations with pH values greater than 8.5 are Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), and Republican River near Rice (SC510). The Republican River near Hardy, NE (SC231) and Rice (SC510) have both drastically reduced their number of excursions since 2004 and neither station has an excursion since then. The Buffalo Creek near Concordia (SC509) has three excursions throughout the period of record, with the most recent of 8.6 occurring in April 2003. Median pH remains relatively consistent among all stations and throughout all seasons, ranging from 7.7 to 8.4 (**Table 10**).

Figure 37. The pH and the relationship between pH and temperature for the Republican River near Hardy, NE (SC231).

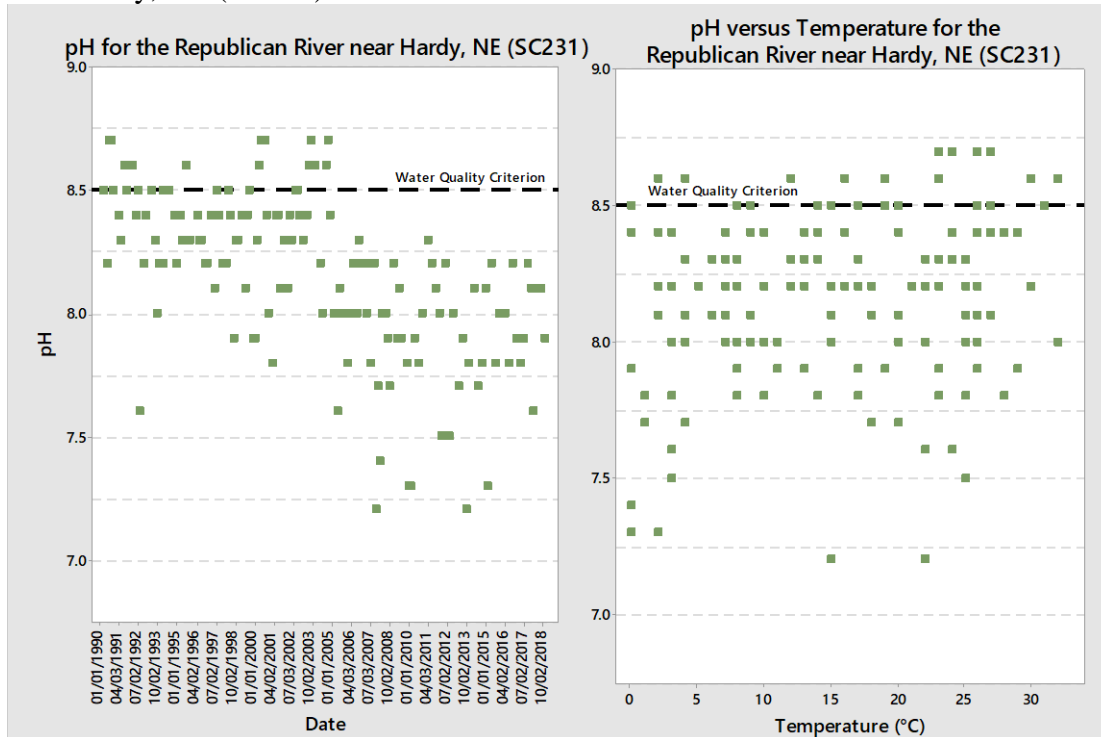


Figure 38. The pH and the relationship between pH and temperature for the Buffalo Creek near Concordia (SC509).

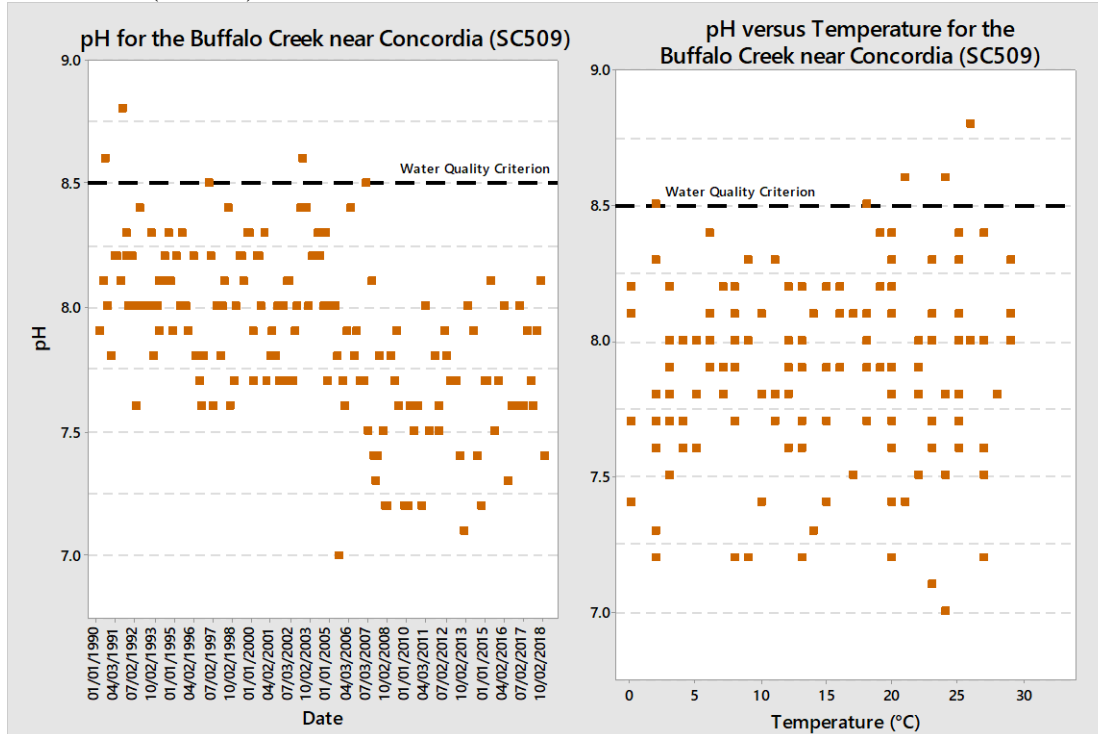


Figure 39. The pH and the relationship between pH and temperature for the Wolf Creek near Concordia (SC707).

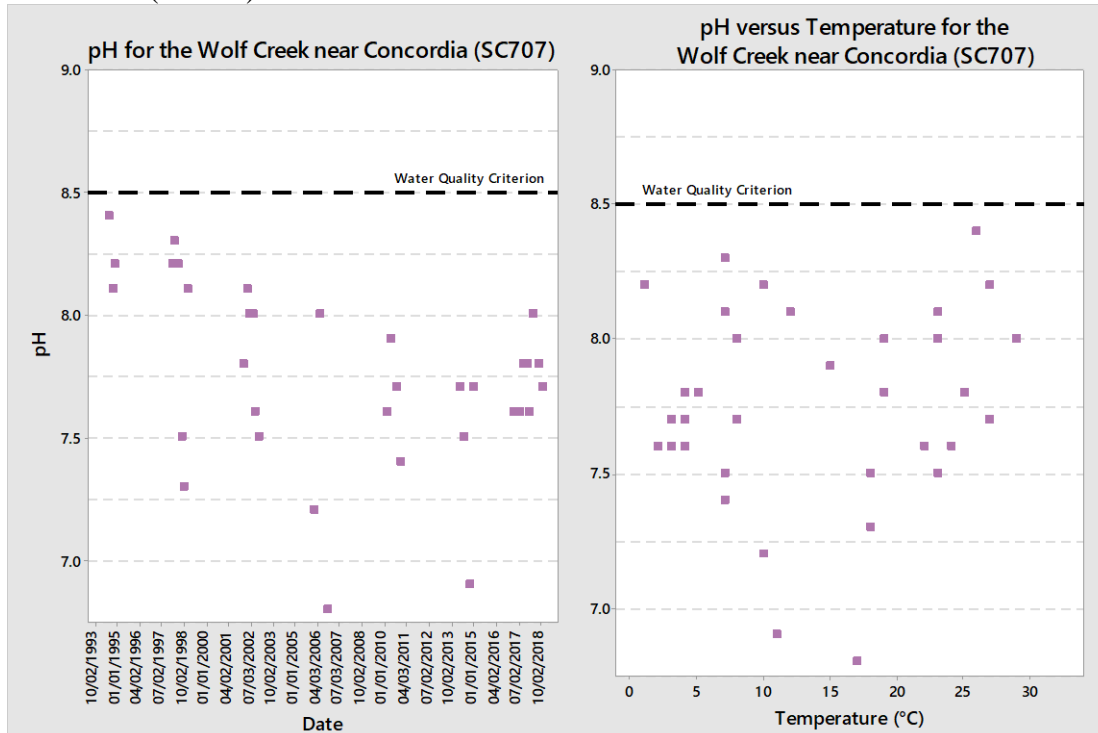
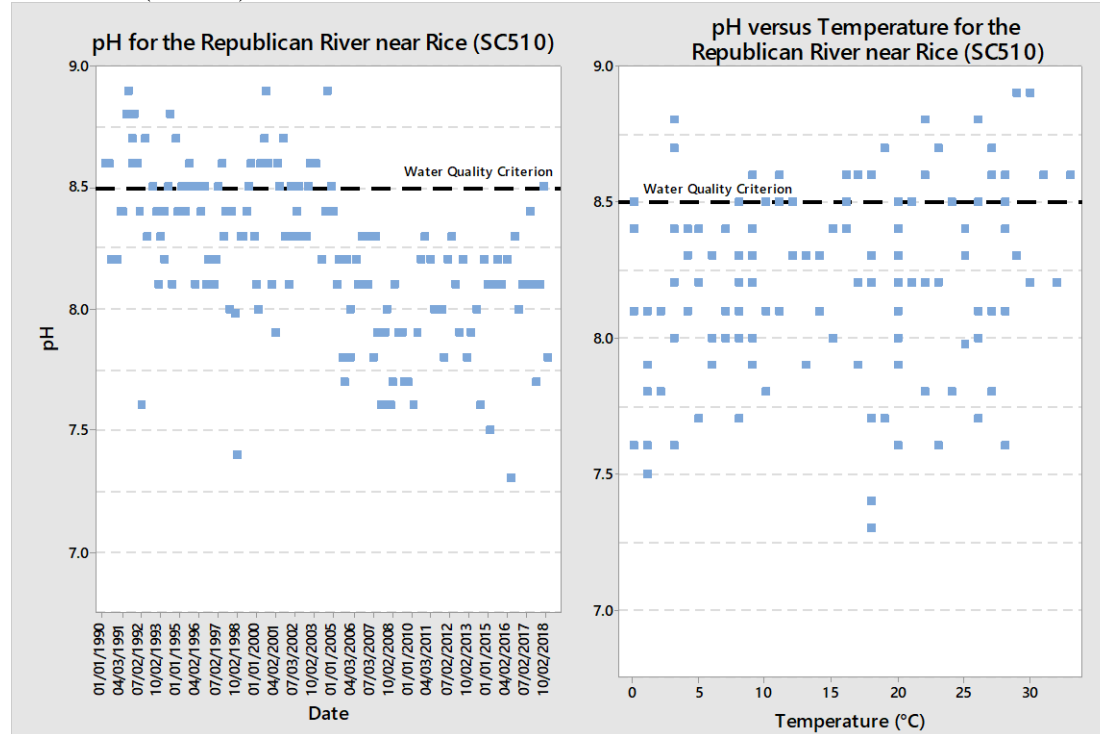


Figure 40. The pH and the relationship between pH and temperature for the Republican River near Rice (SC510).

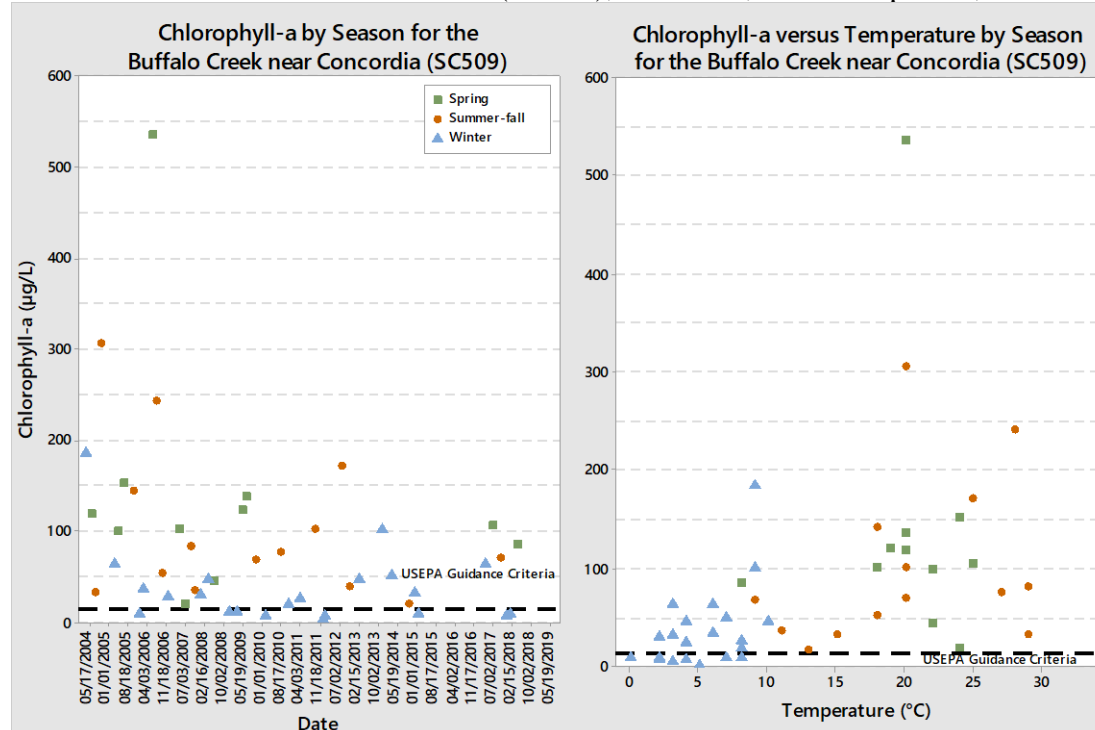


Algal Biomass

Chlorophyll-*a* is a photosynthetic pigment found in algae, and its concentration is commonly used as a measure of the algal biomass present in streams. Because nutrients directly influence primary production, the U.S. Environmental Protection Agency (USEPA) guidance on nutrient criteria for streams establishes a chlorophyll-*a* concentration range of 8 to 15 micrograms per liter ($\mu\text{g/L}$) before overall biology can become adversely impacted (U.S. Environmental Protection Agency, 2000).

There are a limited number of chlorophyll-*a* samples collected for the Republican River from Hardy, NE to Rice. There are no main stem chlorophyll-*a* samples. However, the SP station on Wolf Creek (SPB674) has a single chlorophyll-*a* sample from June 2017 with a concentration of 36 $\mu\text{g/L}$. Additionally, the Buffalo Creek near Concordia (SC509) has a total of 47 samples collected from March 2004 to April 2018 (**Figure 41**). Concentrations range from 2.1 to 535 $\mu\text{g/L}$ with a mean of 80 $\mu\text{g/L}$ and a median of 50 $\mu\text{g/L}$. The USEPA criteria for chlorophyll-*a* concentrations is exceeded during all seasons for the Buffalo Creek near Concordia (SC509). Interpretation of chlorophyll-*a* data collected by KDHE must be qualified by the following: samples are collected from a comparatively small sample set in relation to other parameters and sample collection is based upon visual confirmation of the presence of algae, creating a bias towards high chlorophyll-*a* concentrations in the data set. Because of these factors, chlorophyll-*a* data must be interpreted with caution.

Figure 41. Chlorophyll-*a* and the relationship between chlorophyll-*a* and temperature by season for the Buffalo Creek near Concordia (SC509), March 16, 2004 to April 10, 2018.



Throughout all seasons, chlorophyll-*a* concentrations increase as temperatures increase, though chlorophyll-*a* concentrations are highest during the spring and summer-fall (**Figure 41**). Higher chlorophyll-*a* concentrations generally occur at lower (6-9 mg/L) DO concentrations during the summer-fall, which is an expected trend for seasons with warmer temperatures; however, higher chlorophyll-*a* concentrations also occur at higher (15-17 mg/L) DO concentrations in the spring and winter, indicating that excessive primary productivity may have increased DO concentrations (**Figure 42**). Supersaturated conditions for DO saturation occur in all seasons; higher chlorophyll-*a* concentrations generally coincide with spring and summer-fall, with 111 to 181% DO saturation exhibiting chlorophyll-*a* concentrations ranging from 10 µg/L in winter to 535 µg/L in spring. Throughout all seasons, elevated pH values can coincide with higher chlorophyll-*a* concentrations, as well (**Figure 43**). Chlorophyll-*a* concentrations vary across the range of TP concentrations, with winter chlorophyll-*a* values occasionally exceeding 50 µg/L. Spring and summer-fall chlorophyll-*a* concentrations range from 18 to 535 µg/L across the same range of TP concentrations, highlighting the seasonal component that is integral to driving TP uptake by primary producers.

Understanding the activity of primary producers and their interaction with and effect upon water quality is imperative to interpreting the biological health of a stream. Available chlorophyll-*a* data suggests that primary productivity may be adversely impacting biology for the tributary Buffalo Creek near Concordia (SC509) specifically and the watershed for the Republican River near Hardy, NE to Rice in general. Primary productivity can alter ambient levels of oxygen and the acid-base balance in streams through photosynthesis and respiration, resulting in shifts in the biological community within the stream.

Figure 42. The relationship between chlorophyll-*a* and dissolved oxygen and dissolved oxygen saturation by season for the Buffalo Creek near Concordia (SC509), March 16, 2004 to April 10, 2018.

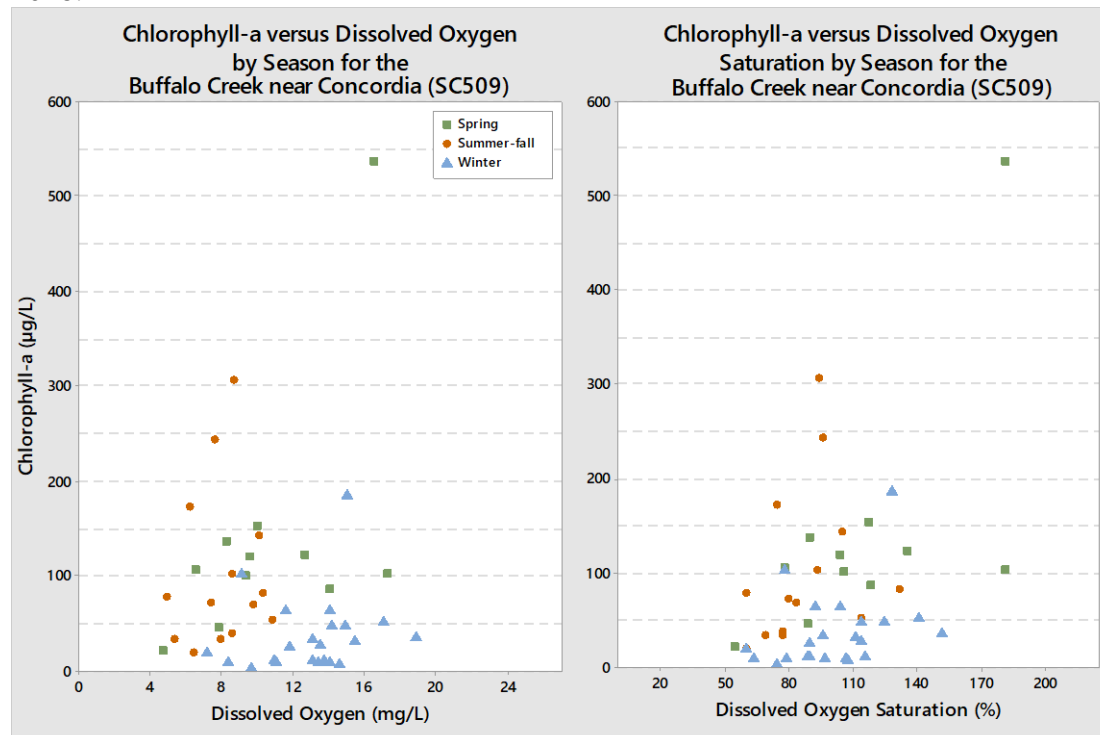
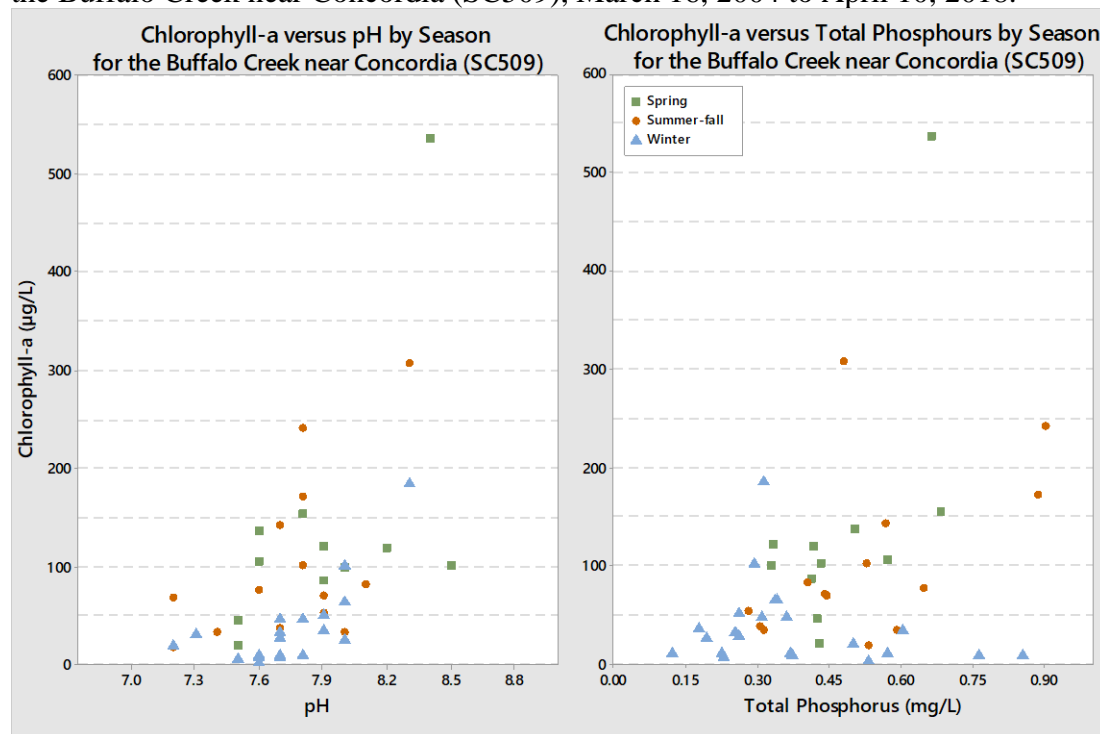


Figure 43. The relationship between chlorophyll-*a* and pH and total phosphorus by season for the Buffalo Creek near Concordia (SC509), March 16, 2004 to April 10, 2018.



Biological Community

Biological data regarding macroinvertebrate organisms and community are collected at KDHE stream biology (SB) stations. The sampled SB stations in the watershed for the Republican River from Hardy, NE to Rice are Republican River near Hardy, NE (SB231) and at Concordia (SB003). The SB stations have been assessed using the Aquatic Life Use Support (ALUS) Index as described in Kansas' 2018 303(d) Methodology. The ALUS Index score consists of five categorizations of biotic conditions:

1. Macroinvertebrate Biotic Index (MBI): A statistical measure that evaluates the effects of nutrients and oxygen demanding substances on aquatic and semi-aquatic macroinvertebrates based on the relative abundance of certain indicator taxa that is specific to the level of order and family.
2. Kansas Biotic Index for Nutrients (KBI-N): A statistical measure mathematically equivalent to the MBI that is restricted to aquatic insect macroinvertebrates and is species specific.
3. Ephemeroptera, Plecoptera, and Trichoptera (EPT): A measure of the richness of the intolerant aquatic EPT taxa within a macroinvertebrate sample used to evaluate the diversity within the sample.
4. EPT Percent of Count (EPT% CNT): The percentage of individuals belonging to the EPT orders in a sample of macroinvertebrates.
5. Shannon's Evenness (SHN EVN): A measure of diversity that describes how evenly distributed the numbers of individuals are among the taxa in a sample.

These metrics are used to establish a score (**Table 12**) which is then translated into an indication of the biotic condition and support category available for aquatic life in the stream (**Table 13**).

Table 12. Aquatic Life Use Support Index metrics with scoring ranges and standardized scores.

MBI	KBI-N	EPT	EPT% CNT	SHN EVN	Score
≤ 4.18	≤ 2.52	≥ 16	≥ 65	≥ 0.849	4
4.19-4.38	2.53-2.64	14-15	56-64	0.826-0.848	3
4.39-4.57	2.65-2.75	12-13	48-55	0.802-0.825	2
4.58-4.88	2.76-2.87	10-11	38-47	0.767-0.801	1
≥ 4.89	≥ 2.88	≤ 9	≤ 37	≤ 0.766	0

Table 13. Aquatic Life Use Support (ALUS) Index score range, interpretation of biotic condition, and aquatic life support category.

ALUS Index Score	Biotic Condition	Support Category
> 16-20	Very Good	Supporting
> 13-16	Good	
> 7-13	Fair	Partially Supporting
> 4-7	Poor	Non-supporting
0-4	Very Poor	

Biotic conditions were sampled annually for the Republican River near Hardy, NE (SB231) from 1990 to 2017 (except for 2010 and 2015) and for the Republican River at Concordia (SB003) from 2013 to 2017 (**Table 14**). The Republican River near Hardy, NE (SB231) has a total of 26 samples with a mean ALUS Index score of 9, indicating biotic conditions are fair and partially supporting of aquatic life. The Republican River at Concordia (SB003) has a total of five

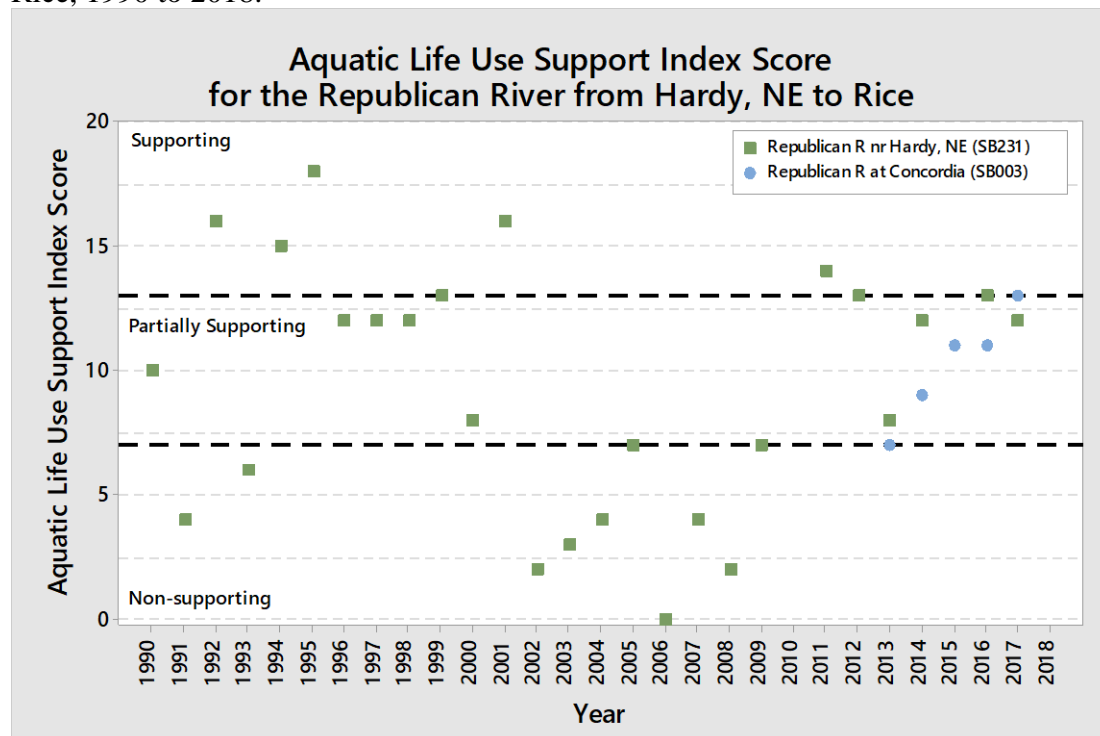
samples with a mean ALUS Index score of 10, indicating biotic conditions are fair and partially supporting of aquatic life, as well.

Table 14. Mean Aquatic Life Use Support (ALUS) Index scores for the Republican River from Hardy, NE to Rice.

Station	Period of Record	Number of Samples	Mean ALUS Index Score	Biotic Condition	ALUS Index Support Category
Republican River near Hardy, NE (SB231)	November 1, 1990 to June 27, 2017	26	9	Fair	Partially Supporting
Republican River at Concordia (SB003)	June 5, 2013 to June 27, 2017	5	10	Fair	Partially Supporting

Although both stations' means indicate that they are partially supporting of aquatic life, the Republican River near Hardy, NE (SB231) has previously had samples that are non-supporting of aquatic life (**Figure 44**). These years typically coincide with periods of extremely high flow, such as 1993, or extremely low flow, such as 2002 to 2006, with the later extreme seemingly inhibiting population recovery for several years. The Republican River at Concordia (SB003) has a much more limited data set and does not capture these extremes to corroborate the downstream effects in the Republican River.

Figure 44. Aquatic Life Use Support Index scores for the Republican River from Hardy, NE to Rice, 1990 to 2018.



Desired Endpoints for Water Quality (Implied Load Capacity) for the Republican River from Hardy, NE to Rice

The ultimate desired water quality (implied load capacity) endpoints of this TMDL for the Republican River from Hardy, NE to Rice, will be to achieve the Kansas Water Quality Standards by eliminating the impacts to aquatic life, domestic water supply, and contact recreation associated with excessive phosphorus and objectionable flora as described in the narrative criteria pertaining to nutrients. There are currently no existing numeric phosphorus criteria in Kansas.

Current USEPA nutrient philosophy is predicated upon 25th percentile stream TP concentrations within an ecoregion to indicate reference conditions. This generalization is not tied to specific biological conditions but represents water quality protection policy guiding USEPA's administration of clean water programs. The current TMDL comprises several USEPA ecoregions, including the aggregate ecoregions Great Plains Grass and Shrublands (IV), South Central Cultivated Great Plains (V), and Corn Belt and Northern Great Plains (VI). The USEPA suggested 25th percentile TP reference benchmarks for streams within these ecoregions are 0.023, 0.068, and 0.076 mg/L, respectively (U.S. Environmental Protection Agency, 2000 and 2001). Within these ecoregions, the Republican River from Hardy, NE to Rice primarily falls within the Level IV Ecoregions Smoky Hills (27a), Rolling Plains and Breaks (27b), Flint Hills (28a), and Loess and Glacial Drift Hills (47i). Assessment of 49 KDHE SC stations within these Level IV Ecoregions and the Kansas and Lower Republican River Basin with TP data from 2000 to 2018 indicates a 25th percentile of medians of 0.120 mg/L and a 50th percentile of medians of 0.216 mg/L (**Table 15; Appendix A**).

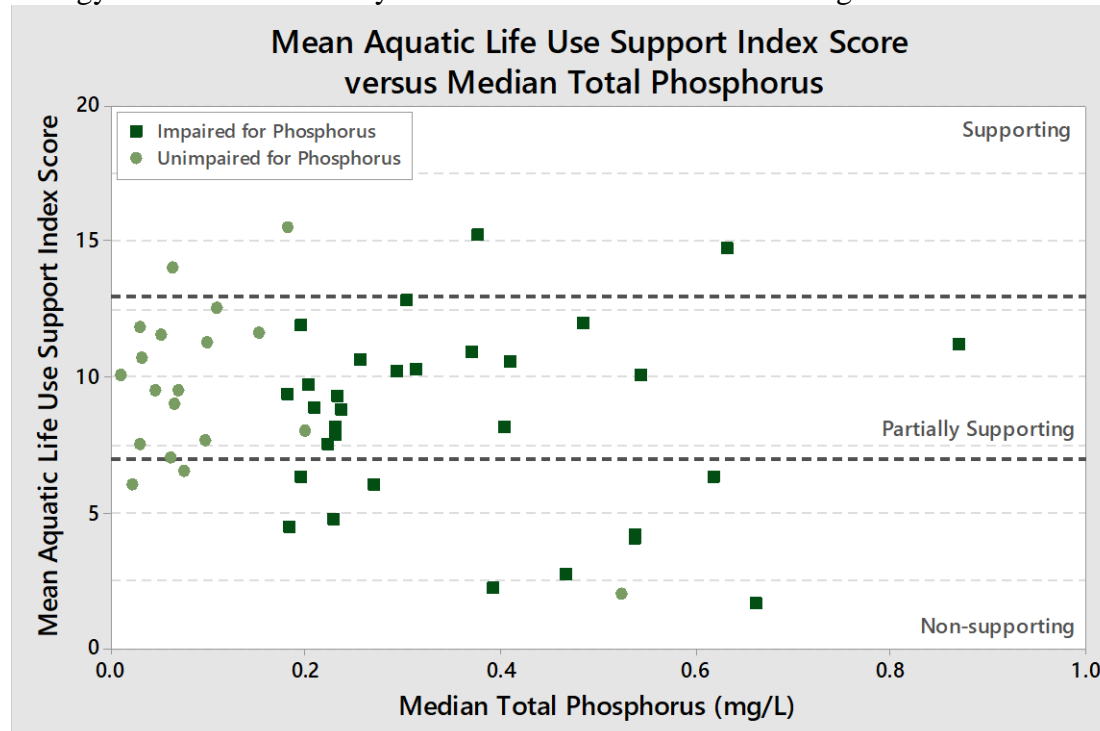
Table 15. Summary of Kansas Department of Health and Environment (KDHE) stream chemistry stations within the Level IV Ecoregions and Kansas and Lower Republican River Basin from 2000 to 2018.

USEPA Level IV Ecoregions	Number of KDHE Stations	Number of Samples	25 th Percentile of Medians (mg/L)	50 th Percentile of Medians (mg/L)	75 th Percentile of Medians (mg/L)
Smoky Hills (27a)	12	620	0.233	0.303	0.401
Rolling Plains and Breaks (27b)	4	147	0.235	0.278	0.451
Flint Hills (28a)	21	1,120	0.046	0.117	0.177
Loess and Glacial Drift Hills (47i)	12	603	0.188	0.223	0.263
Aggregated Level IV Ecoregions	49	2,490	0.120	0.216	0.309

Within the aggregate ecoregions, there are 51 KDHE stations with biology and chemistry data within the Level III Ecoregions Central Great Plains (27), Flint Hills (28), and Western Corn Belt Plains (47). An analysis of the mean ALUS Index versus the median TP concentration indicates that there is generally a decline in biology with increasing TP concentrations (**Figure 45**). There are two SB station fully supporting biology that are unimpaired for TP, and the majority of unimpaired stations are partially supporting biology. This variability in relationship of the mean ALUS Index versus the median TP concentration is due to the numerous factors impacting biological health. Such variability supports an adaptive management approach to reduce current TP concentrations and loads, rather than establishing a single, definitive

threshold. Therefore, this TMDL seeks to establish an adaptive management approach in order to observe and respond to biological metrics to assess the impact of TP reductions. As such, the primary measure of phosphorus load reduction in the TMDL for impaired segments of the Republican River from Hardy, NE to Rice will be an improved ALUS Index. An ALUS Index score greater than 13 at SB stations will serve to establish that the biological community reflects recovered or renewed diversity and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Figure 45. Aquatic Life Use Support (ALUS) Index versus median total phosphorus for stream biology and stream chemistry stations within the Level III Ecoregions from 2000 to 2018.

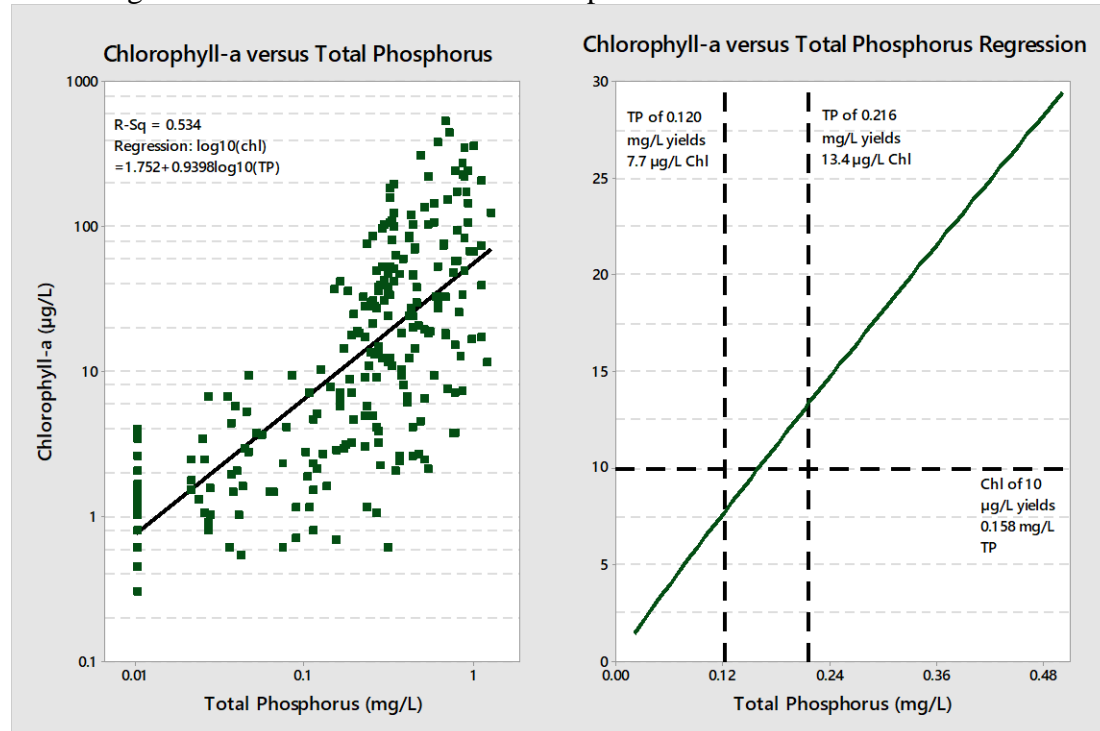


Of the SC stations within the Level IV Ecoregions and the Kansas and Lower Republican River Basin used for the TP milestone analysis, 13 SC stations with a total of 250 samples have corresponding chlorophyll-*a* data. An analysis of the relationship between chlorophyll-*a* versus TP indicates that there is a positive correlation between the variables (**Figure 48**). In this relationship, the TP 25th percentile of medians of 0.120 mg/L yields a chlorophyll-*a* concentration of 7.7 µg/L and the TP 50th percentile of medians of 0.216 mg/L yields a chlorophyll-*a* concentration of 13.4 µg/L. These chlorophyll-*a* concentrations bracket the desired chlorophyll-*a* endpoint of 10 µg/L. Likewise, a chlorophyll-*a* concentration of 10 µg/L yields a TP concentration 0.158 mg/L. The chlorophyll-*a* concentration will serve as an additional biological measure of nutrient loading reduction in order to assess improvements in primary productivity and address its impacts as described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Furthermore, secondary indicators of the health of the aquatic biological community will be assessed at SC stations. Dissolved oxygen concentrations will be monitored to ensure

concentrations are greater than 5.0 mg/L. According to the Kansas Water Quality Standards, concentrations below this are low enough to put aquatic life under stress. Dissolved oxygen saturation will also be monitored for indication of overactive primary productivity, as indicated by supersaturated values greater than 110%. The pH will be monitored, as well, to ensure that overactive primary productivity is not altering stream chemistry; values should remain between 6.5 and 8.5 in order to protect aquatic life according to the Kansas Water Quality Standards.

Figure 46. Chlorophyll-*a* versus total phosphorus for stream chemistry stations within the Level IV Ecoregions and the Kansas and Lower Republican River Basin from 2000 to 2018.



The numeric endpoints for stream segments in this TMDL, as measured for the Buffalo Creek near Concordia (SC509), Wolf Creek near Concordia (SC707), and Republican River near Rice (SC510), indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than 13 at SB stations.
2. Median sestonic chlorophyll-*a* concentrations less than or equal to 10 µg/L at SC stations.
3. Dissolved oxygen concentrations greater than 5.0 mg/L at SC stations.
4. Dissolved oxygen saturation less than 110% at SC stations.
5. Values within the range of 6.5 to 8.5 for pH at SC stations.

As there are currently no numeric phosphorus criteria in Kansas, the series of endpoints established by this TMDL will be the measure used to indicate full support of aquatic life, domestic water supply, and contact recreation in the Republican River from Hardy, NE to Rice. All five endpoints must initially be maintained over three consecutive years to constitute full support of the designated uses of the impaired stream segments in this TMDL, as measured at KDHE stations Buffalo Creek near Concordia (SC509), Wolf Creek near Concordia (SC707),

Republican River at Concordia (SB003), and Republican River near Rice (SC510). These endpoints will be evaluated periodically as phosphorus levels decline in the watershed, with achievement of the ALUS Index endpoint indicating the restored status of the aquatic life use in the river. Simultaneous achievement of the chlorophyll-*a*, DO, DO saturation, and pH endpoints will signal that TP reductions are addressing the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products, thereby restoring the domestic water supply and contact recreation uses in the river. After the endpoints are attained, simultaneous digression of these endpoints more than once every three years on average constitutes a resumption of the TP impairment at the respective station unless the TP impairment is delisted through the 303(d) process.

This TMDL seeks to establish an adaptive management approach for TP by establishing phased TP milestones (**Table 16**). The Phase I milestone will be a TP concentration of 0.216 mg/L, reflecting the 50th percentile of medians for KDHE SC stations within Level IV Ecoregions and the Kansas and Lower Republican River Basin. Total phosphorus concentrations approaching the Phase I milestone will cue the examination for altered, improved biological conditions at the SB station within the Republican River. Should aquatic life not respond, a Phase II milestone will commence with a TP concentration of 0.120 mg/L, reflecting the 25th percentile of medians for KDHE SC stations within the Level IV Ecoregions and the Kansas and Lower Republican River Basin.

Table 16. Current median total phosphorus (TP) concentrations from 2000 to 2018 and Phase I and II TP milestones for the Republican River from Hardy, NE to Rice.

Station	Current Condition (2000-2018)	Phase I		Phase II	
	Median TP (mg/L)	TP Milestone (mg/L)	TP Reduction (%)	TP Milestone (mg/L)	TP Reduction (%)
Buffalo Cr nr Concordia (SC509)	0.453	0.216	52	0.120	74
Wolf Cr nr Concordia (SC707)	0.396	0.216	45	0.120	70
Republican R nr Rice (SC510)	0.300	0.216	28	0.120	60

3. SOURCE INVENTORY AND ASSESSMENT

The Republican River TMDL Watershed comprises the watersheds for the Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), Wolf Creek near Concordia (SC707), and Republican River near Rice (SC510). These watersheds predominantly lie within Cloud, Jewell, Republic, and Smith counties. Within this section, point sources, livestock, land use, water diversions, population, on-site waste systems, and contributing runoff are considered by watershed and county.

Point Sources

There are a total of 12 National Pollution Discharge Elimination System (NPDES) permitted facilities within the Republican River TMDL Watershed (**Table 17; Figure 2**). Of the 12 permitted facilities, none are located in the Republican River near Hardy, NE (SC231) Watershed, five are located in the Buffalo Creek near Concordia (SC509) Watershed, none are located in the Wolf Creek near Concordia (SC707) Watershed, and seven are located in the Republican River near Rice (SC510) Watershed. Additionally, there are no Municipal Separate Storm Sewer System (MS4) permits within the Republican River TMDL Watershed.

Dischargers to the Buffalo Creek near Concordia (SC509) Watershed

There are a total of five NPDES permitted facilities within the Buffalo Creek near Concordia (SC509) Watershed. Of the five permitted facilities, four are non-discharging lagoons and one is a municipal discharging lagoon.

The non-discharging lagoons are operated by the cities of Formoso, Jamestown, Jewell, and Randall. The City of Formoso operates a three-cell lagoon and the other facilities all operate two-cell lagoons. These facilities are prohibited from discharging, their systems do not monitor for TP, and they are not expected to contribute to the TP impairment in the watershed.

The municipal discharging lagoon is operated by the City of Mankato. This facility treats domestic waste in a three-cell lagoon system. It is required to monitor for TP quarterly, when discharging. According to the facility's Discharge Monitoring Report (DMR) period of record (September 2004 to October 2018), the City of Mankato discharged to the Republican River via Middle Buffalo Creek during approximately 81% of the quarters. The city has reported discharging a mean concentration of 1.39 mg/L TP from August 2016 to October 2018. The discharging lagoon for the City of Mankato will be assigned a TP wasteload allocation (WLA) under this TMDL.

Dischargers to the Republican River near Rice (SC510) Watershed

There are a total of seven NPDES permitted facilities within the Republican River near Rice (SC510) Watershed. Of the seven permitted facilities, two are concrete operation pit dewatering facilities, two are non-discharging lagoons, one is a municipal discharging lagoon, one is an industrial mechanical treatment facility, and one is a municipal mechanical WWTF.

The two concrete operation pit dewatering facilities are operated by Abram Ready Mix, Inc. – Concordia Plant and Concordia Ready-Mix. Both facilities generate wastewater by washing concrete trucks. Domestic waste from the former is treated by the municipal system and from the latter is treated by a septic system. These facilities do not monitor for TP and they are not expected to contribute to the TP impairment in the watershed.

The two non-discharging lagoons are operated by the cities of Republic and Scandia. The facilities are both two-cell lagoon systems that are prohibited from discharging. They do not monitor for TP and are not expected to contribute to the TP impairment in the watershed.

The municipal discharging lagoon in the watershed is operated by the City of Courtland. The facility treats domestic waste in a three-cell lagoon system. It is required to monitor for TP

quarterly, when discharging. According to the facility's DMR period of record (July 2004 to December 2018), the City of Courtland discharged to the Republican River via Beaver Creek via an unnamed tributary during approximately 93% of the quarters. The city has reported discharging a mean concentration of 2.79 mg/L TP from October 2010 to December 2018. The discharging lagoon for the City of Mankato will be assigned a TP wasteload allocation (WLA) under this TMDL.

The industrial mechanical treatment facility is operated by Nesika Energy – Ethanol Plant. This facility ferments grain and distills ethanol. Settling tanks are used to separate solids from process water and process water is bag-filtered before discharge. Nesika Energy – Ethanol Plant discharges process water to either the Republican River or an adjacent feedlot lagoon via a pipeline. All domestic waste is treated with a septic system. According to the facility's DMR period of record (April 2008 to December 2018), the facility discharged 0.0614 MGD to the Republican River. This facility is required to monitor TP annually and has monitored TP since 2008, as well. The mean TP concentration of this facility's discharge is 0.243 mg/L. In total, the facility discharged 0.125 lbs/day TP. The Nesika Energy – Ethanol Plant is assigned a TP WLA under this TMDL.

The municipal mechanical WWTF is operated by the City of Concordia. According to the facility's DMR period of record (January 2000 to December 2018), this facility currently operates at 0.606 MGD, making it the largest discharger to the Republican River TMDL Watershed. The WWTF is not designed for nutrient removal. Currently, the City of Concordia WWTF has a monthly monitoring requirement for TP. From 2000 to 2018, the discharge from this facility has a mean TP concentration of 2.92 mg/L, or 14.77 lbs/day. The City of Concordia WWTF is assigned a TP WLA under this TMDL.

Table 17. National Pollution Discharge Elimination System (NPDES) facilities in the Republican River TMDL Watershed.

Permittee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	Monitoring Frequency	Current Flow (MGD)	Current Total Phosphorus Mean (mg/L)
Buffalo Creek near Concordia (SC509)								
City of Formoso	M-LR10-NO01	KSJ000371	Non-discharging lagoon	NA	April 30, 2024	NA	0	NA
City of Jamestown	M-LR12-NO01	KSJ000373	Non-discharging lagoon	NA	April 30, 2024	NA	0	NA
City of Jewell	M-LR13-NO01	KSJ000374	Non-discharging lagoon	NA	April 30, 2024	NA	0	NA
City of Randall	M-LR20-NO01	KSJ000366	Non-discharging lagoon	NA	February 28, 2024	NA	0	NA
City of Mankato	M-LR16-OO02	KS0095231	Municipal discharging lagoon	Republican River via Middle Buffalo Creek	March 31, 2020	Quarterly	–	1.39

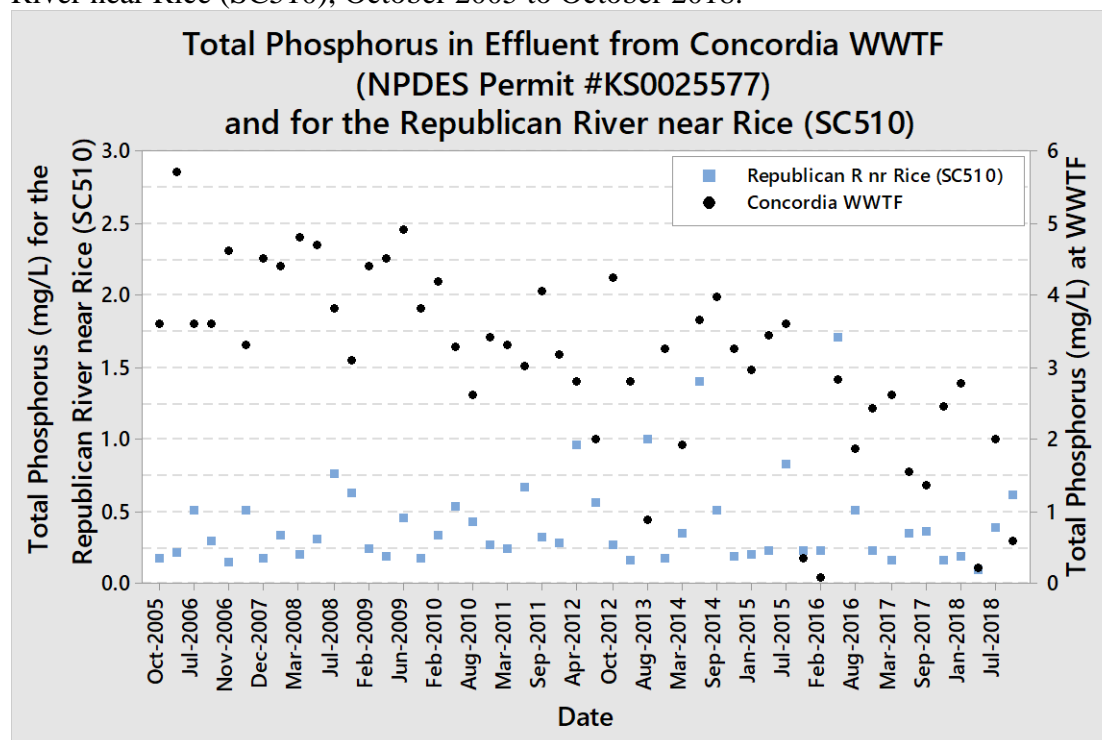
Permittee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	Monitoring Frequency	Current Flow (MGD)	Current Total Phosphorus Mean (mg/L)
Republican River near Rice (SC510)								
Abram Ready Mix, Inc. - Concordia Plant	I-LR08-PR02	KSG110080	Concrete operation pit dewatering	Unregistered Stream	September 30, 2022	NA	–	–
Concordia Ready-Mix	I-LR08-PR01	KSG110064	Concrete operation pit dewatering	Unnamed Tributaries to the Republican River	September 30, 2022	NA	–	–
City of Republic	M-LR21-NO01	KSJ000367	Non-discharging lagoon	NA	April 30, 2024	NA	0	NA
City of Scandia	M-LR22-NO01	KSJ000368	Non-discharging lagoon	NA	March 31, 2024	NA	0	NA
City of Courtland	M-LR09-OO01	KS0083399	Municipal discharging lagoon	Republican River via Beaver Creek via Unnamed Tributary	March 31, 2020	Quarterly	–	2.79
Nesika Energy - Ethanol Plant	I-LR22-PO01	KS0096539	Industrial mechanical treatment facility	Republican River via Pipeline	December 31, 2021	Annually	0.0614	0.243
City of Concordia	M-LR08-OO01	KS0025577	Municipal wastewater treatment facility	Republican River	June 30, 2020	Monthly	0.606	2.92

Definitions: – - Data not available; NA - Not applicable

Major Dischargers to the Republican River TMDL Watershed

The dominant point source contributing to the TP load for the Republican River TMDL Watershed is the WWTF operated by the City of Concordia, upstream of the Republican River near Rice (SC510; **Figure 47**). The influence of the WWTF effluent was evaluated by comparing the monthly TP concentrations in the WWTF effluent to the monthly TP concentrations at the Republican River station, where concomitant data were available. Increases and decreases in TP concentrations in WWTF effluent can correspond to a likewise response in TP concentrations within the Republican River. Additionally, the WWTF does show a trend of decreasing TP concentrations throughout the period of record.

Figure 47. Total phosphorus in effluent from the wastewater treatment facility (WWTF) operated by the City of Concordia (NPDES Permit #KS0025577) contributed to the Republican River near Rice (SC510), October 2005 to October 2018.



Livestock and Waste Management Systems

There are 29 certified or permitted Animal Feeding Operations (AFOs) and Concentrated Animal Feeding Operations (CAFOs) within the Republican River TMDL Watershed. Of these, three are located in the Republican River near Hardy, NE (SC231) Watershed, 10 are located in the Buffalo Creek near Concordia (SC509) Watershed, zero are located in the Wolf Creek near Concordia (SC707) Watershed, and 16 are located in the Republican River near Rice (SC510) Watershed (**Figure 2; Table 18**). There are two CAFOs large enough to require a federal permit (A-LRRP-C001/KS0116459 and A-LRRP-C002/KS0097969), which are located in the Republican River (SC510) near Rice Watershed. In addition to certified or permitted AFOs and CAFOs, there are unregistered operations below the permitting threshold in the Republican River TMDL Watershed. While these operations are smaller than AFOs and CAFOs, they are unregulated, frequently grazing cattle which have access to in-stream watering. As such, these facilities may contribute to TP loading in the watershed.

All of these livestock facilities have waste management systems designed to retain an anticipated two weeks of normal wastewater from their operations and contain a 25-year, 24-hour rainfall/runoff event, as well. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. Additionally, facility waste management systems are designed to minimize runoff entering operations and detain runoff emanating from operations. It is unlikely TP loading would be attributable to properly operating permitted facilities, though extensive loading may occur if any of these facilities were in violation and discharged.

Table 18. Certified or permitted Animal Feeding Operations and Concentrated Animal Feeding Operations in the Republican River TMDL Watershed.

Kansas Permit Number	County	Livestock Type	Livestock Total
<i>Republican River (SC231) near Hardy, NE</i>			
A-LRJW-BA09	Jewell	Beef	125
A-LRJW-BA12	Jewell	Beef	50
A-LRJW-S023	Jewell	Beef/Swine	1,450
<i>Buffalo Creek (SC509) near Concordia</i>			
*	Jewell	Beef	100
A-LRJW-B005	Jewell	Beef	400
A-LRJW-B006	Jewell	Beef	999
A-LRJW-BA01	Jewell	Beef	250
A-LRJW-BA02	Jewell	Beef	200
A-LRJW-BA06	Jewell	Beef	200
A-LRJW-BA07	Jewell	Beef	600
A-LRJW-BA08	Jewell	Beef	600
A-LRJW-BA11	Jewell	Beef	205
A-LRJW-MA01	Jewell	Dairy	40
<i>Republican River (SC510) near Rice</i>			
A-LRCD-B001	Cloud	Beef	999
A-LRCD-BA01	Cloud	Beef	600
A-LRCD-BA06	Cloud	Beef	575
A-LRCD-BA08	Cloud	Beef	290
A-LRJW-BA04	Jewell	Beef	100
A-LRRP-B001	Republic	Beef	999
A-LRRP-B003	Republic	Beef	999
A-LRRP-BA03	Republic	Beef	300
A-LRRP-BA05	Republic	Beef	450
A-LRRP-BA06	Republic	Beef	200
A-LRRP-BA07	Republic	Beef	240
A-LRRP-C001	Republic	Beef	25,000
A-LRRP-C002	Republic	Beef	3,000
A-LRRP-LA01	Republic	Beef/Sheep	1,600
A-LRRP-MA01	Republic	Dairy	25
A-LRRP-S025	Republic	Swine	720

Definitions: * - Application or registration submitted; **Bold** - Federal permit

The total number of livestock within Cloud, Jewell, Republic, and Smith counties is approximately 156,000 head (**Table 19**; U.S. Department of Agriculture, 2019). The primary livestock industry in all counties is cattle, with cattle and calves numbering approximately: 32,000 in Cloud County; 31,000 in Jewell County; 50,000 in Republic County; and 31,000 in Smith County. From 2012 to 2017, cattle and calves have increased in Cloud and Republic counties by 2 and 47%, respectively, and decreased in Jewell and Smith counties by 2 and 7%, respectively. Overall, there is an increase in livestock of 13%.

Table 19. Agricultural census results for livestock by county from 2007, 2012, and 2017 (U.S. Department of Agriculture, 2019).

Livestock	Total, 2007	Total, 2012	Total, 2017	Percent Change
Cloud County				
Cattle and Calves	33,234	31,067	31,821	2
Sheep and Lambs	93	131	–	–
Poultry	1,084	551	804	46
Hogs and Pigs	3,071	–	–	–
Goats	282	744	237	-68
Jewell County				
Cattle and Calves	39,295	31,978	31,442	-2
Sheep and Lambs	3,773	2,717	–	–
Poultry	372	203	780	284
Hogs and Pigs	4,364	–	–	–
Goats	486	318	34	-89
Republic County				
Cattle and Calves	45,092	34,253	50,498	47
Sheep and Lambs	3,069	–	3,457	–
Poultry	693	544	251	-54
Hogs and Pigs	94	21	–	–
Goats	348	271	179	-34
Smith County				
Cattle and Calves	35,953	33,636	31,443	-7
Sheep and Lambs	1,190	894	1,400	57
Poultry	505	596	1,682	182
Hogs and Pigs	6,473	–	1,629	–
Goats	705	562	218	-61

Definition: – - No data

Land Use

Cloud, Jewell, Republic, and Smith counties have an approximate total of 1,700 farms and 1,130,000 acres of cropland (**Table 20**; U.S. Department of Agriculture, 2019). Of the four counties, Republic County contains the largest number of farms and Smith County contains the greatest acreage of cropland. Overall, there is a decrease in numbers of farms of 6% and an increase in acres in cropland of 3%.

The 2011 National Land Cover Database indicates the dominant land use in the watershed is cultivated crops, with 57% of the watershed currently used for crop cultivation (**Figure 48**; **Table 21**). Cultivated cropland has an increased potential for nutrient runoff from fertilizers, which can contribute to TP loads in the watershed. Grassland, including pastureland and hay fields, is the second most prevalent land use in the watershed, with 33% of the watershed in grassland.

Table 20. Agricultural census results for farms and cropland by county from 2007, 2012, and 2017 (U.S. Department of Agriculture, 2019).

County	Year	Total Farms in Cropland	Total Cropland (acres)
Cloud	2017	360	203,186
	2012	384	208,841
	2007	428	253,789
	Percent Change (%), 2012 to 2017	-10	-18
Jewell	2017	399	293,527
	2012	403	294,769
	2007	478	290,760
	Percent Change (%), 2012 to 2017	-16	1
Republic	2017	509	269,090
	2012	533	258,537
	2007	616	282,884
	Percent Change (%), 2012 to 2017	-13	-9
Smith	2017	393	363,167
	2012	453	334,362
	2007	432	285,271
	Percent Change (%), 2012 to 2017	5	17

Figure 48. The 2011 National Land Cover Database map for land cover in the Republican River TMDL Watershed.

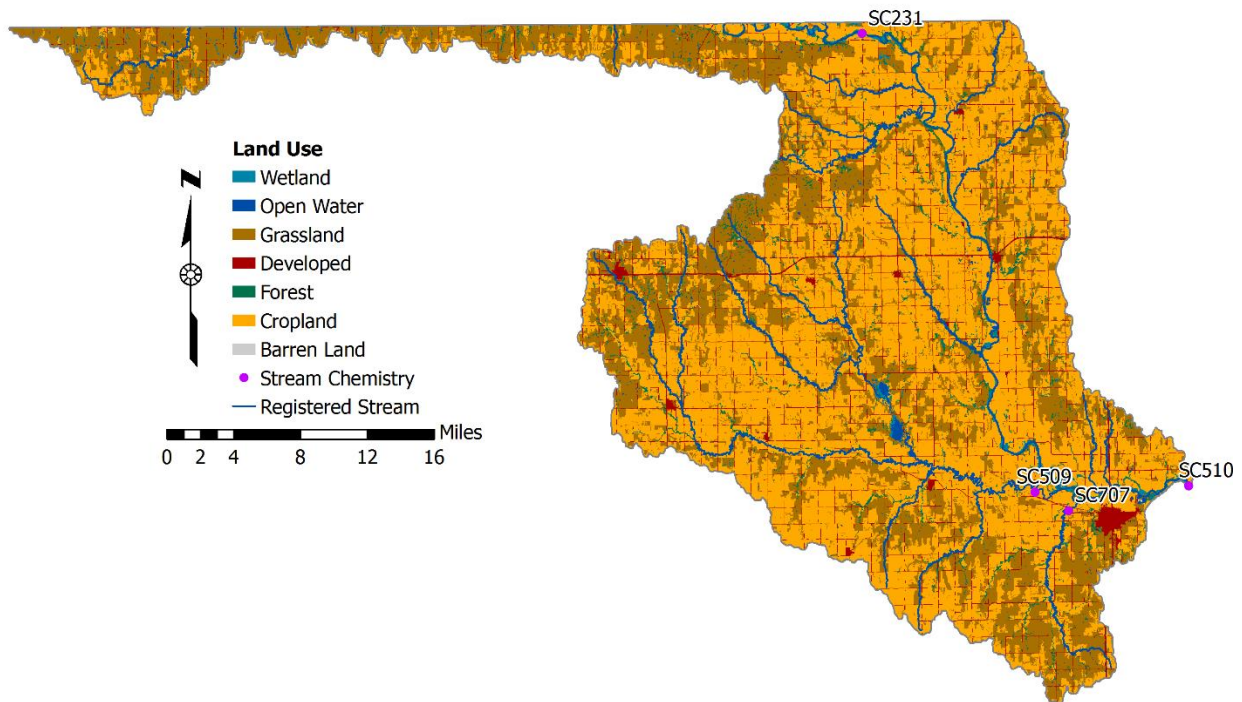


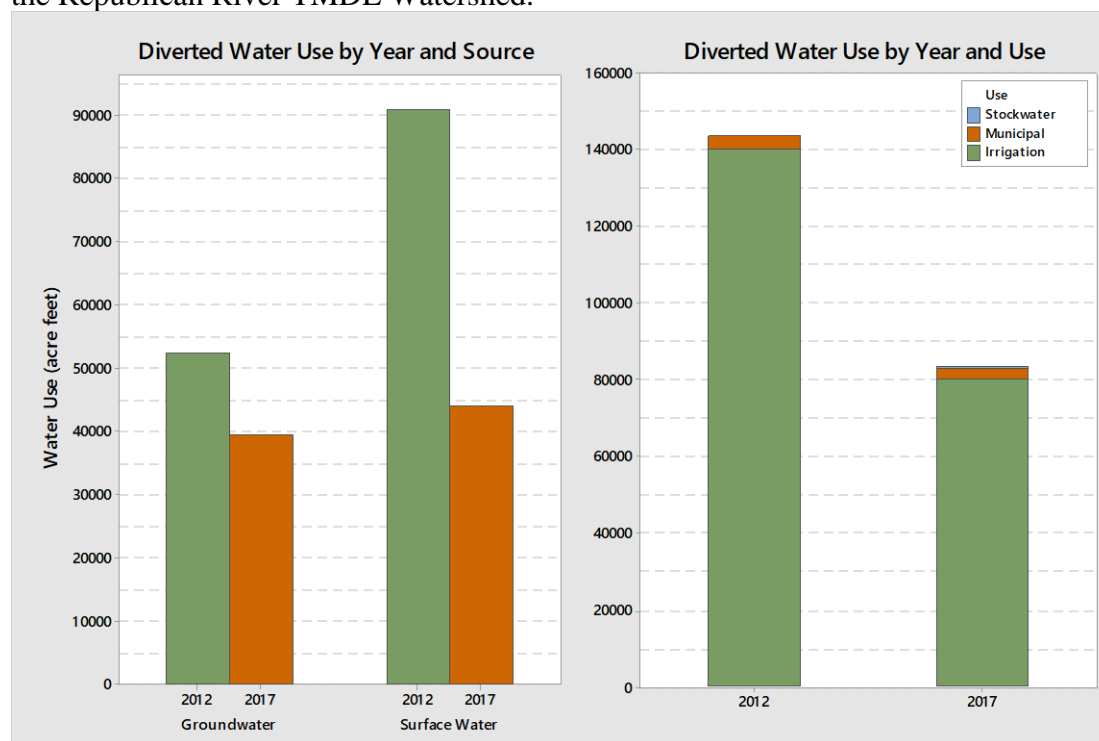
Table 21. Data from the 2011 National Land Cover Database for land cover by percent in the Republican River TMDL Watershed.

Land Use (percent)						
Open Water	Developed	Barren	Forest	Grassland	Cultivated Crops	Wetlands
1	5	0	3	33	57	1

Diversions

Within Cloud, Jewell, Republic, and Smith counties, surface water is diverted in greater quantities than groundwater (**Figure 49**; Water Information Management and Analysis System, 2019). This is especially notable during dry years, such as 2012, when surface water diversions nearly double groundwater diversions. The predominant use for diverted water in these counties is irrigation. Additional diversions for municipal and stockwater uses tend to remain stable regardless of environmental conditions; irrigation, however, is the dominant source of increased water diversions during dry years, as demonstrated in 2012.

Figure 49. Diverted water by source and use according to the Water Information Management and Analysis System (WIMAS; 2019) for a dry (2012) and normal (2017) year for counties in the Republican River TMDL Watershed.



There are a total of 2,762 diversions among all the counties, and Republic County has the greatest number of diversions, with 1,059 diversions (**Table 22**). These four counties have an approximate total of 384,000 acres of irrigated land as of 2017, a decrease of 18% since 2012 (U.S. Department of Agriculture, 2019). Cloud and Republic counties both have the most irrigated acres and Jewell and Smith counties both have irrigated land acreage below 100,000 acres. All counties have decreased their irrigated land by 8 to 36% since 2012.

Table 22. Agricultural census results for irrigated land by county from 2007, 2012, and 2017 (U.S. Department of Agriculture, 2019) and permitted water diversions according to the Water Information Management and Analysis System (WIMAS; 2019).

County	Category	2007	2012	2017	Percent Change (%), 2007 to 2012
Cloud	Irrigated Land (acres)	147,922	136,299	111,209	-18
	Number of Diversions	–	956	956	0
Jewell	Irrigated Land (acres)	60,173	79,371	50,646	-36
	Number of Diversions	–	316	316	0
Republic	Irrigated Land (acres)	154,564	153,091	141,166	-8
	Number of Diversions	–	1,059	1,059	0
Smith	Irrigated Land (acres)	60,759	97,283	81,310	-16
	Number of Diversions	–	431	431	0
Total	Irrigated Land (acres)	423,418	466,044	384,331	-18
	Number of Diversions	–	2,762	2,762	0

Definition: -- No data

The U.S. Department of Agriculture collects census data for the cost of fertilizer, lime, and soil conditioners applied to agricultural land (**Table 23**). Overall, the cost of fertilizer, lime, and soil conditioners within the counties totaled approximately \$45 million in 2017 and has decreased by 18% since 2012. All counties have experienced a decline in fertilizer, lime, and soil conditioners cost ranging from 12 to 24%.

Table 23. Agricultural census results for cost of fertilizer by county from 2007, 2012, and 2017 (U.S. Department of Agriculture, 2019).

County	Cost (\$), 2007	Cost (\$), 2012	Cost (\$), 2017	Percent Change (%), 2007 to 2012
Cloud	9,935,000	9,122,000	7,984,000	-12
Jewell	10,218,000	16,037,000	12,263,000	-24
Republic	12,233,000	15,711,000	12,215,000	-22
Smith	8,102,000	14,851,000	13,007,000	-12
Total	40,488,000	55,721,000	45,469,000	-18

Population Density

According to the 2010 U.S. Census, the population of all four counties in the watershed is approximately 21,000 and has decreased by 12% since 2000 (**Table 24**). Cloud County encompasses the cities of Concordia and Jamestown, Jewell County encompasses the cities of Formoso, Jewell, Mankato, Randall, and Scottsville, Republic County encompasses the cities of Courtland, Republic, and Scandia, and Smith County encompasses no cities for the watershed considered. Of these, the City of Concordia is the largest urban center. In general, populations are declining in all counties and in the majority of these cities, with populations falling near or below the Kansas Water Office projections for 2040.

Table 24. City and county census results from 2000 and 2010 (U.S. Census Bureau, 2010) and population projections for 2040 (Kansas Water Office, 2002).

Location	Population, 2000	Population, 2010	Population Projection, 2040	Population Change, 2000 to 2010 (%)
Cloud County	10,268	9,533	10,625	-7
Concordia	5,714	5,395	7,028	-6
Jamestown	399	286	230	-28
Jewell County	3,791	3,077	2,792	-19
Formoso	129	93	137	-28
Jewell	483	432	475	-11
Mankato	976	869	612	-11
Randall	90	65	81	-28
Scottsville	21	25	15	19
Republic County	5,835	4,980	4,606	-15
Courtland	334	285	203	-15
Republic	161	116	105	-28
Scandia	436	372	249	-15
Smith County	4,536	3,853	3,249	-15

On-Site Waste Systems

Of the four counties, the populations of Jewell, Republic, and Smith are entirely rural, with 100% of their populations classified as rural (**Table 25**; U.S. Census Bureau, 2010). The population of Cloud County is more diverse, with a population that is 44% rural and 56% urban. Urban populations are typically served by municipal sewer systems; however, rural populations do not have access to this service and use septic systems. According to the U.S. Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Load (STEPL), there are a total of 1,250 septic systems located in the Republican River TMDL Watershed. Septic systems in the state of Kansas typically have an estimated 10-15% failure rate (Electric Power Research Institute, 2000). Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed. However, because of their small flows and the proclivity of phosphorus to adsorb to soil, failing on-site septic systems are considered a minor source of TP loading within the watershed and are not expected to significantly contribute to TP impairment in the Republican River.

Table 25. Census results by urban and rural population and county from 2010 (U.S. Census Bureau, 2010).

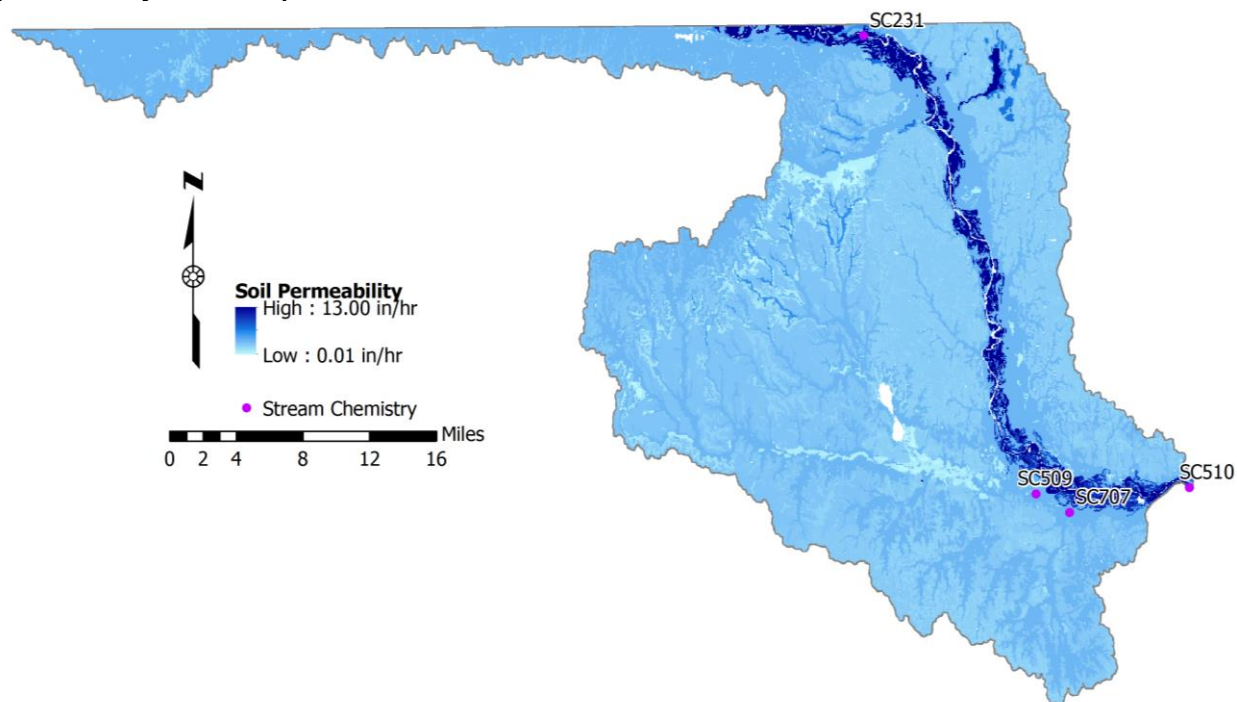
County	Classification	Population, 2010	Percent (%)
Cloud	Rural	4,193	44
	Urban	5,340	56
Jewell	Rural	3,077	100
	Urban	0	0
Republic	Rural	4,980	100
	Urban	0	0
Smith	Rural	3,853	100
	Urban	0	0

Contributing Runoff

Runoff conditions can occur as a result of either infiltration-excess (precipitation exceeds the infiltration rate of the soil) or saturation-excess (precipitation falls on soils saturated due to an elevated water table), causing overland flow (Juracek, 2000). Overland flow can impact the quality of water entering streams, thereby impacting water-quality loads. Soil permeability categories in Kansas have been defined by the following criteria in inches per hour (in/hr): very high (3.43 in/hr), high (2.86 in/hr), moderate (2.29 in/hr), low (1.71 in/hr), very low (1.14 in/hr), and extremely low (0.57 in/hr).

According to the Natural Resources Conservation Service (NRCS) State Soil Geographic Database (STATSGO), the Republican River TMDL Watershed has a soil permeability range of 0.01 to 13 in/hr (**Figure 50**). Within the watershed, 74% of the area has a soil permeability less than 1.71 in/hr. Overall, the watershed has a mean soil permeability of 1.31 in/hr, placing the watershed in the low soil permeability category.

Figure 50. Map of Natural Resources Conservation Service State Soil Geographic Database soil permeability in the Republican River TMDL Watershed.



Background Levels

Phosphorus is present over the landscape and in the soil profile. It is also present in terrestrial and aquatic biota. Wildlife can contribute to phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The following TMDLs, or load capacities (LC), are based upon the desired endpoints for aquatic life condition, chlorophyll-*a*, dissolved oxygen concentration, dissolved oxygen saturation, and pH concentration. All of these endpoints should improve to a level that provides full attainment of designated uses as phosphorus concentrations decrease in the Republican River. The LC is based on TP management milestones and the estimated flow conditions in the river. Once TP loading for the upstream station Republican River near Hardy, NE (SC231) is accounted for, incremental loading for the Republican River TMDL Watershed can be estimated by subtracting the upstream load from downstream loading capacity.

Load Capacity

These TMDLs are established in two phases to reduce TP concentrations and loadings within the river and will require periodic assessment of aquatic life conditions to determine compliance with the narrative nutrient criteria as TP concentrations and loadings decline. The Phase I TP milestone is set at 0.216 mg/L, which is the 50th percentile of the median concentrations of KDHE SC stations within the Level IV Ecoregions and the Kansas and Lower Republican River Basin. Presuming one or more of the endpoints are not met at the end of Phase I, Phase II will commence with a TP milestone of 0.120 mg/L, which is the 25th percentile of the median concentrations of KDHE SC stations within the Level IV Ecoregions and the Kansas and Lower Republican River Basin. Further reductions in TP concentrations and loads for Phase II will be accomplished through enhanced implementation of controls of both point and nonpoint sources in the watershed. For both Phase I and Phase II, total LCs are calculated according to the previously described TP milestones and the flow conditions in the Republican River TMDL Watershed.

For purposes of comparing current TP loading conditions in the river to the expected reduction in TP loading, the current condition was evaluated using the median TP concentration at each SC station from 2000 to 2018. Sampled TP concentrations at all three stations were converted to loads for seasonal comparison with their respective TMDLs.

Wasteload Allocations

The total Phase I TP WLA for point sources for the Republican River TMDL Watershed is 16.1 lbs/day (**Table 26**). Under Phase II, the total TP WLA for point sources will be 10.4 lbs/day. Both of these WLAs are more stringent than the WLAs calculated in the Milford Lake TMDL for eutrophication (Kansas Department of Health and Environment, 2013). Therefore, this TMDL is considered protective of the downstream Milford Lake and supersedes previously established WLAs.

The TP WLAs in this TMDL are calculated using concentrations for each facility according to the following: concrete operations, quarries, and non-discharging lagoons are calculated at a TP concentration of 0 mg/L; the industrial mechanical treatment facility is calculated at a TP concentration equal to the facility's mean DMR TP concentration; municipal discharging lagoons are calculated at a TP concentration of 2.00 mg/L, an effluent concentration common in Kansas lagoons; the Phase I municipal mechanical WWTF is calculated at a TP concentration of 1.00 mg/L; the Phase II municipal mechanical WWTF is calculated at a TP concentration of

0.500 mg/L. The TP WLAs assigned to all municipal facilities are based upon current design flows for each facility. The TP WLAs assigned to all industrial facilities are based upon their current mean discharge rate.

Buffalo Creek near Concordia (SC509) Watershed

The four facilities assigned a Phase I and Phase II TP WLA of 0 lbs/day are the non-discharging lagoons operated by the cities of Formoso, Jamestown, Jewell, and Randall. The Phase I and Phase II WLA for the discharging lagoon system operated by the City of Mankato is calculated with the TP WLA concentration of 2.00 mg/L at design flow. Accordingly, the Phase I and Phase II TP WLA assigned to the City of Mankato lagoon is 2.27 lbs/day, or 829 pounds per year (lbs/year).

Republican River near Rice (SC510) Watershed

The four facilities assigned a Phase I and Phase II TP WLA concentration of 0 lbs/day are the concrete operations operated by Abram Ready Mix, Inc. – Concordia Plant and Concordia Ready-Mix and the non-discharging lagoons operated by the cities of Republic and Scandia. The Phase I and Phase II WLA for the discharging lagoon system operated by the City of Courtland is calculated with the TP WLA concentration of 2.00 mg/L at design flow. Accordingly, the Phase I and Phase II TP WLA assigned to the City of Courtland lagoon is 0.877 lb/day, or 320 lbs/year. The Phase I and Phase II WLA for the industrial mechanical treatment facility operated by the Nesika Energy – Ethanol Plant is calculated with the current mean DMR reported TP WLA concentration of 0.243 mg/L at the facility's current mean discharge rate. Accordingly, the Phase I and Phase II TP WLA assigned to this facility is 0.125 lb/day, or 45 lbs/year. The remaining facility within this watershed is the municipal mechanical WWTF operated by the City of Concordia. The design flow for this facility is 1.35 MGD. The Phase I TP WLA concentration for this facility is a concentration of 1.00 mg/L. Accordingly, the Phase I TP WLA assigned to this facility is 11.3 lbs/day, or 4,125 lbs/year. The Phase II TP WLA concentration for this facility will be calculated at a concentration of 0.500 mg/L.

Reserve Wasteload Allocation

A reserve WLA is calculated at 10% for the entirety of the Republican River TMDL Watershed in order to accommodate future development within the watershed. The Phase I WLA is 14.6 lbs/day, resulting in a reserve WLA of 1.46 lbs/day. Reserve WLAs apply to the watershed terminus at Republican River near Rice (SC510) and may be apportioned throughout the Republican River TMDL Watershed from Hardy, NE to Rice.

Livestock

All AFOs and CAFOs within the Republican River TMDL Watershed are assigned a WLA of 0 lbs/day.

Load Allocation

The LA is established to account for nonpoint sources of TP in the watershed. The LA is the remainder of the LC after all other allocations are accounted for. Loads from nonpoint source TP are assumed to be minimal during low flow conditions and grow proportionately as flow conditions increase, thereby accounting for increased runoff during precipitation events. The

application of agricultural BMPs in riparian zones near cropland and livestock areas should continue in order to abate and reduce nonpoint source TP loading in this watershed.

Table 26. Phase I total phosphorus wasteload allocations for discharging National Pollution Discharge Elimination System (NPDES) permitted facilities for the Republican River TMDL Watershed.

Permittee	Kansas Permit Number	NPDES Permit Number	Facility Type	Design Flow (MGD)	Anticipated Total Phosphorus Wasteload Allocation Concentration (mg/L)	Total Phosphorus Daily Wasteload Allocation (lbs/day)	Total Phosphorus Annual Wasteload Allocation (lbs/year)
City of Mankato	M-LR16-OO02	KS0095231	Municipal discharging lagoon	0.136	2.00	2.27	829
Total Phosphorus Wasteload Allocation for the Buffalo Creek near Concordia (SC509)						2.27	829
Abram Ready Mix, Inc. - Concordia Plant	I-LR08-PR02	KSG110080	Concrete operation pit dewatering	—	0	0	0
Concordia Ready-Mix	I-LR08-PR01	KSG110064	Concrete operation pit dewatering	—	0	0	0
City of Courtland	M-LR09-OO01	KS0083399	Municipal discharging lagoon	0.0525	2.00	0.877	320
Nesika Energy - Ethanol Plant	I-LR22-PO01	KS0096539	Industrial mechanical treatment facility	0.0614	0.243	0.125	45
City of Concordia	M-LR08-OO01	KS0025577	Municipal wastewater treatment facility	1.35	1.00	11.3	4,125
Total Phosphorus Wasteload Allocation for the Republican River near Rice (SC510)						12.3	4,490
Total Phosphorus Sub-watershed Total Wasteload Allocation						14.6	5,319
Total Phosphorus Total Reserve Wasteload Allocation						1.46	533
Total Phosphorus Total Wasteload Allocation						16.1	5,877

Definition: — Data not available

The described TMDLs, or LCs, are delineated below for the Buffalo Creek near Concordia (SC509; **Table 27; Figure 51**), Wolf Creek near Concordia (SC707; **Table 28; Figure 52**), and Republican River near Rice (SC510; **Table 29; Figure 53**) watersheds.

Figure 51. Total phosphorus Phase I Total Maximum Daily Load for the Buffalo Creek near Concordia (SC509).

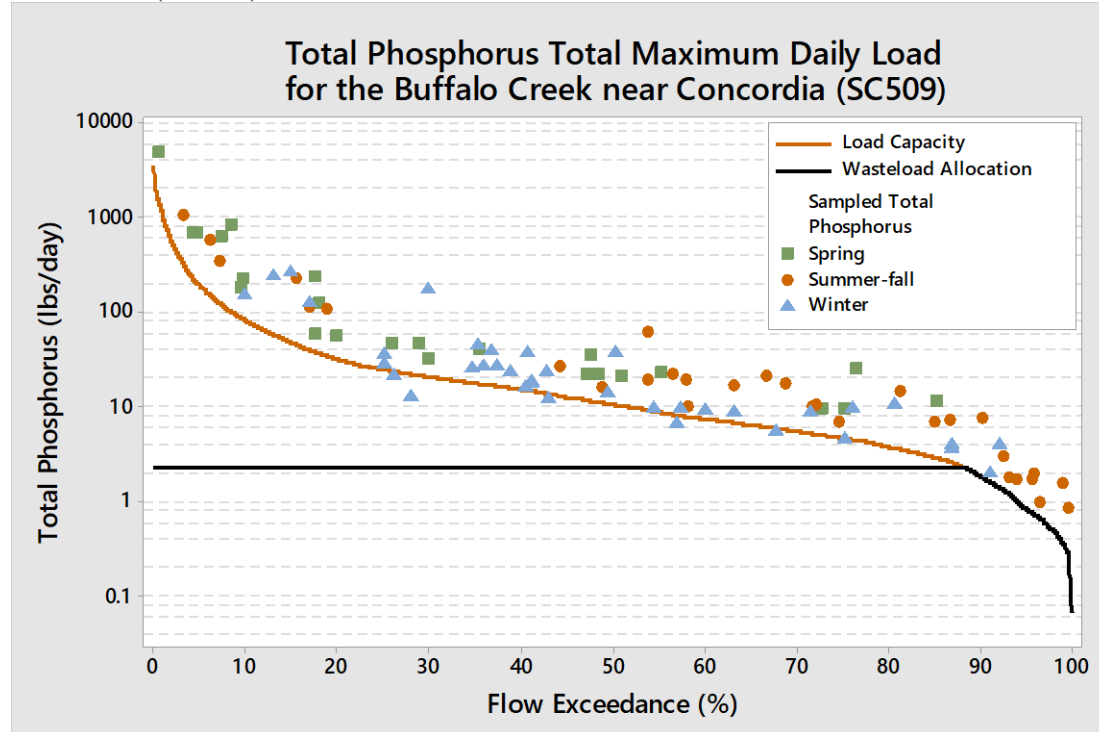


Table 27. Phase I and phase II current load conditions (based upon the median total phosphorus concentration from 2000 to 2018), total load capacity, and load capacity apportionment for the Buffalo Creek near Concordia (SC509).

Flow Exceedance (%)	Flow at Terminus (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I					
90	2	4	1.9	1.9	0.0
75	4	10	4.6	2.3	2.3
50	9	22	10.4	2.3	8.1
25	21	51	24.5	2.3	22.2
10	71	173	82.3	2.3	80.0
Phase II					
90	2	4	1.0	1.0	0.0
75	4	10	2.5	2.3	0.2
50	9	22	5.8	2.3	3.5
25	21	51	13.6	2.3	11.3
10	71	173	45.7	2.3	43.4

Figure 52. Total phosphorus Phase I Total Maximum Daily Load for the Wolf Creek near Concordia (SC707).

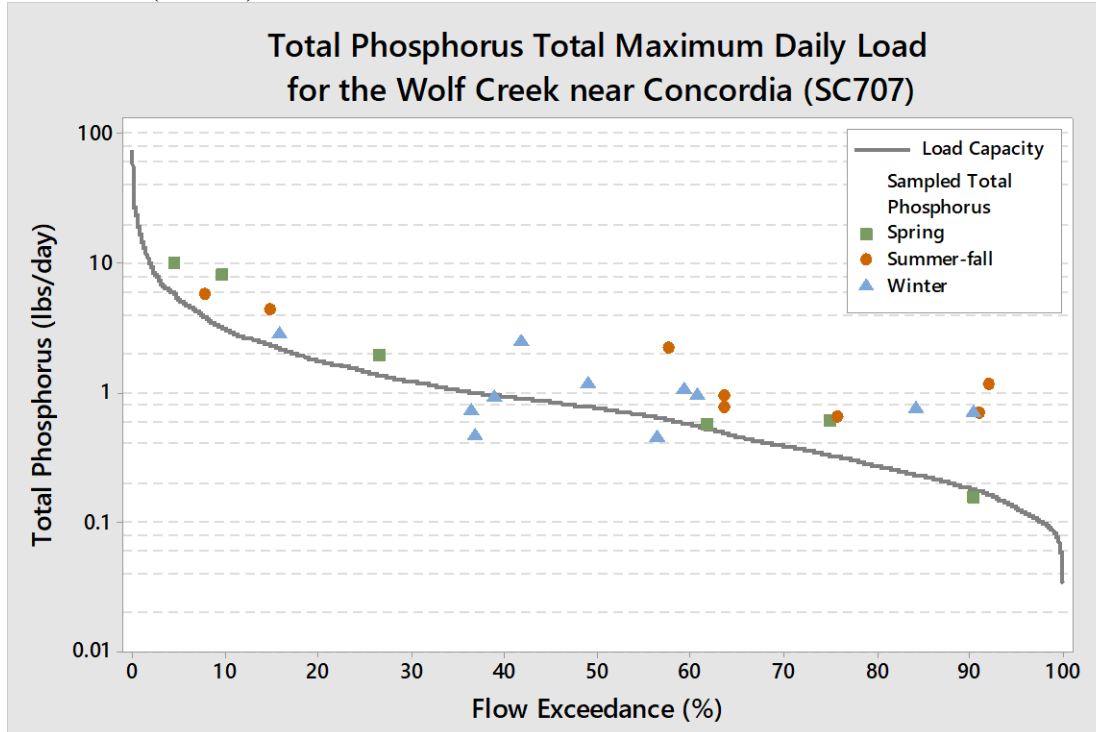


Table 28. Phase I and phase II current load conditions (based upon the median total phosphorus concentration from 2000 to 2018), total load capacity, and load allocation for the Wolf Creek near Concordia (SC707).

Flow Exceedance (%)	Flow at Terminus (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Load Allocation (lbs/day)
Phase I				
1	0.2	0	0.2	0.2
75	0.3	1	0.3	0.3
50	1	1	0.7	0.7
25	1	3	1.4	1.4
10	3	6	3.1	3.1
Phase II				
90	0.2	0	0.1	0.1
75	0.3	1	0.2	0.2
50	1	1	0.4	0.4
25	1	3	0.8	0.8
10	3	6	1.7	1.7

Figure 53. Total phosphorus Phase I Total Maximum Daily Load for the Republican River near Rice (SC510).

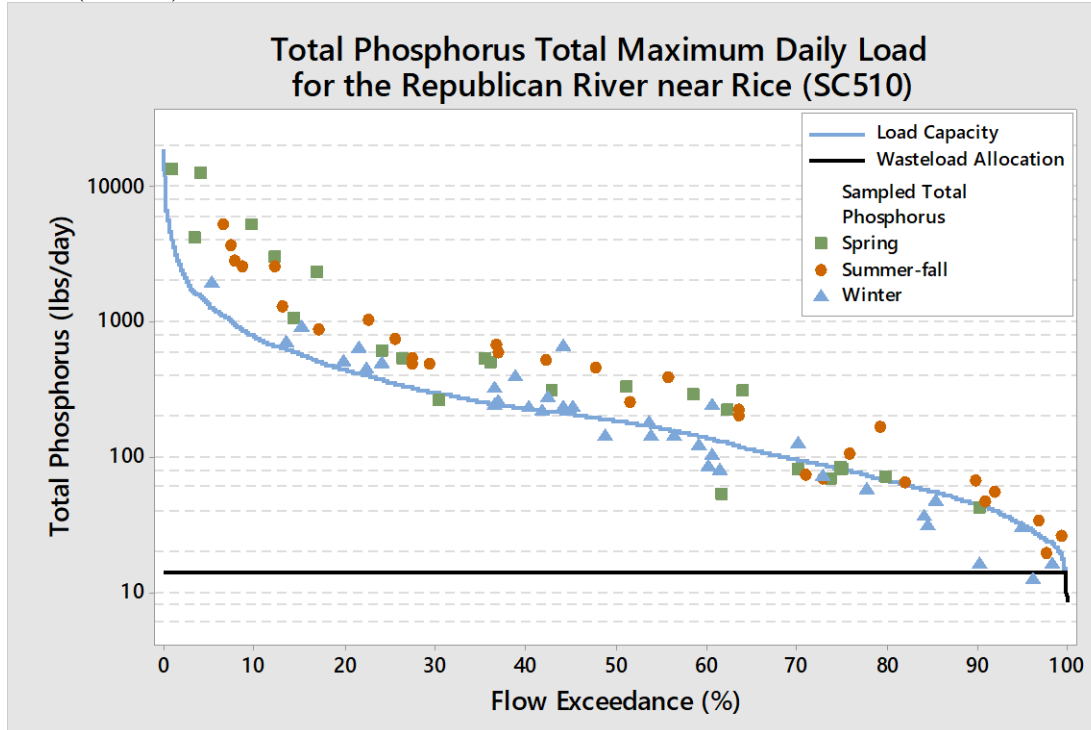


Table 29. Phase I and phase II current load conditions (based upon the median total phosphorus concentration from 2000 to 2018), total load capacity, and load capacity apportionment for the Republican River near Rice (SC510).

Flow Exceedance (%)	Flow at Terminus (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Reserve Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I						
90	38	61	44.3	12.3	1.46	30.54
75	68	110	79.2	12.3	1.46	65.45
50	156	253	182.3	12.3	1.46	168.54
25	299	485	349.3	12.3	1.46	335.54
10	645	1,045	752.4	12.3	1.46	738.64
Phase II						
90	38	61	24.6	6.64	1.46	16.5
75	68	110	44.0	6.64	1.46	35.9
50	156	253	101.3	6.64	1.46	93.2
25	299	485	194.1	6.64	1.46	186.0
10	645	1,045	418.0	6.64	1.46	409.9

Defined Margin of Safety

The margin of safety safeguards against the uncertainty in TP loading in the Republican River. This TMDL incorporates conservative assumptions to establish an implicit margin of safety. First, five endpoints are established which must be met for three consecutive years before achieving attainment of the water quality standards. Second, concurrently reducing TP and nitrogen discharged from municipal WWTPs is emphasized in order to diminish the often synergistic effects these nutrients have on aquatic life. Third, design flows are used for all point source WLAs, despite the current operation of most facilities under design flow. Fourth, some facilities are assigned WLAs when it is likely that they do not contribute nutrient loads.

Priority HUC12s

Although this TMDL does require implementation of point source treatment improvements, reductions in nonpoint sources from BMP implementation in those HUC12s most impacted by TP loading will be necessary to achieve the TMDL (**Figure 54; Table 30**). The Republican River TMDL Watershed consists of 35 HUC12s. According to STEPL, the Republican River TMDL Watershed high priority HUC12s are: 102500170103, 102500170105, 102500170106, 102500170107, 102500170201, and 102500170205 for the Buffalo Creek near Concordia (SC509) Watershed; 102500170302 for the Wolf Creek near Concordia (SC707) Watershed; and 102500160805, 102500160901, 102500160902, 102500160903, 102500170202, 102500170203, 102500170204, 102500170303, 102500170304, and 102500170310 for the Republican River near Rice (SC510) Watershed. Proactive entities may implement BMPs at any time, with an emphasis on priority HUC12s likely yielding the greatest TP reductions to the Republican River TMDL Watershed.

Figure 54. Map of priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load for the Republican River TMDL Watershed.

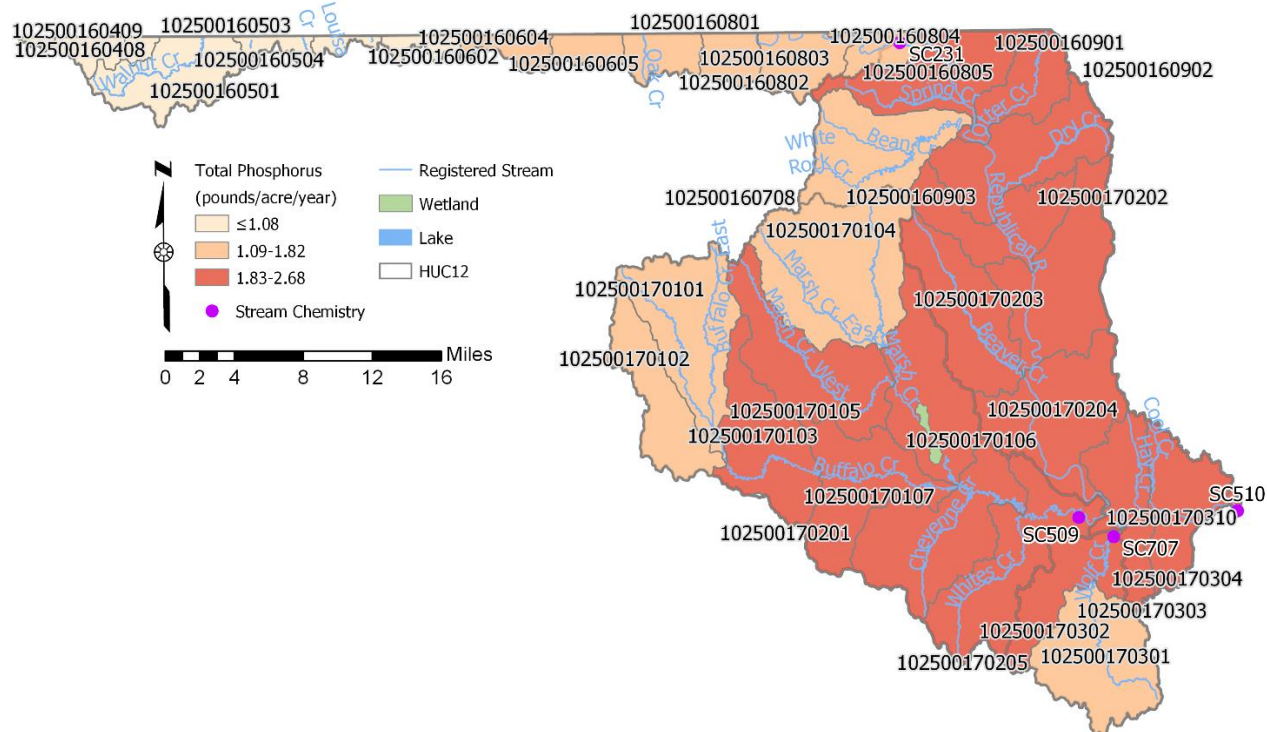


Table 30. Priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load for the Republican River TMDL Watershed.

Watershed	Land Area (acres)	Total Phosphorus (lbs/year)	Total (lbs/year/acre)
102500160408	13,973	9,710	0.69
102500160504	32,868	28,074	0.85
102500160602	23,575	22,271	0.94
102500160409	18,219	19,757	1.08
102500160501	36,011	26,485	0.74
102500160507	27,079	26,821	0.99
102500160503	14,263	11,857	0.83
102500160605	34,685	45,457	1.31
102500160604	52,891	67,472	1.28
102500160801	23,439	42,735	1.82
102500160803	38,717	54,013	1.40
102500170301	34,186	51,842	1.52
102500170101	21,510	30,293	1.41
102500160802	27,239	44,843	1.65
102500160804	30,635	68,679	2.24
102500170104	12,577	32,755	2.60
102500170102	24,183	54,164	2.24
102500160708	17,401	44,022	2.53
102500170304	26,787	40,529	1.51
102500170201	17,588	31,720	1.80
102500170303	22,920	50,623	2.21
102500170310	39,135	64,517	1.65
102500170105	27,665	56,411	2.04
102500170205	23,294	49,618	2.13
102500170302	23,588	51,308	2.18
102500170106	29,599	58,768	1.99
102500170107	27,538	61,859	2.25
102500170103	23,766	63,626	2.68
102500160902	27,492	61,892	2.25
102500160805	27,688	57,795	2.09
102500170202	25,353	36,817	1.45
102500170204	15,494	32,472	2.10
102500160903	15,868	31,886	2.01
102500160901	16,025	31,534	1.97
102500170203	21,504	43,658	2.03

Definition: **Bold** - Priority HUC12s

State Water Plan Implementation Priority

Due to the prevalence of high TP concentrations in the Republican River, this TMDL initially focuses on reducing TP loading from point sources, such as permitted NPDES municipal WWTFs. However, further reductions in TP loadings will need to be achieved through effective riparian and land management. Due to the need to reduce the high nutrient loads in the Republican River, this TMDL will be **High Priority** for implementation.

Nutrient Reduction Framework Priority Ranking

This watershed lies within the Middle Republican (HUC8 10250016) and Lower Republican (HUC8 10250017) subbasins. These subbasins contribute to the Middle Kansas (HUC8 10270102) and Lower Kansas (HUC8 10270104) subbasins, which are among the top 16 HUC8s targeted for state action to reduce nutrients.

5. IMPLEMENTATION

Desired Implementation Activities

1. Make operational changes in the municipal WWTF to reduce the phosphorus load.
2. Facilitate wastewater reuse for treated municipal wastewater.
3. Renew state and federal permits and inspect permitted facilities for permit compliance.
4. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the streams and drainage channels in the watershed.
5. Implement and maintain conservation farming practices—including conservation rotation, no-till farming, and contour farming—in order to reduce runoff and cropland erosion of agricultural areas in the watershed.
6. Perform extensive soil testing to ensure excess phosphorus is not unnecessarily applied.
7. Ensure labeled application rates for chemical fertilizers are followed to reduce runoff.
8. Implement nutrient management plans and ensure that land-applied manure is properly managed to reduce runoff.
9. Establish pasture management practices, including proper stock density, to reduce soil erosion and storm runoff.
10. Ensure proper on-site waste system operations in proximity to main stem and tributary segments.
11. Install alternative livestock watering systems and relocate livestock feeding areas away from riparian areas.
12. Establish alternative livestock foraging areas, collaborate with producers to develop areas for grazing cover crops, and implement rotational grazing systems.
13. Provide education and outreach opportunities on topics such as soil health, nutrient management, and livestock management.
14. Support BMP implementation efforts of the Milford Lake Watershed Restoration and Protection Strategy (WRAPS) and Milford Lake Watershed Regional Conservation Partnership Program (RCPP).

Implementing these practices will reduce nutrient loading in the Republican River; however, an emphasis on agricultural BMPs will be needed in this watershed in order to address nonpoint sources of loading and meet Phase I of this TDML (**Table 31**).

Table 31. Nonpoint source load reduction required to meet the Phase I TMDL for the Republican River from Hardy, NE to Rice for median flow conditions.

Station	Current Condition (lbs/year)	Load Capacity (lbs/year)	Wasteload Allocation (lbs/year)	Load Allocation Reduction (lbs/year)	Load Allocation Reduction (%)
Republican R nr Rice (SC510)	92,345	66,540	5,037	30,843	33

Implementation Program Guidance

NPDES and State Permits – KDHE

- a. Continue to monitor influent to and effluent from the permitted discharging WWTFs, encourage wastewater reuse and irrigation disposal, and ensure compliance and proper operation of WWTFs to control phosphorus in wastewater effluent.
- b. Establish permit limits after 2019, as determined by KDHE, with the initial implementation of goals and appropriate schedules of compliance for permits issued prior.
- c. Manage the WLA for the watershed to accommodate growth as needed.
- d. Manure management plans, detailing proper land application rates and practices, will be implemented to prevent runoff of applied manure.
- e. Inspect permitted livestock facilities to ensure compliance.
- f. Inspect new permitted livestock facilities for integrity of applied pollution prevention technologies.
- g. Apply pollution prevention technologies to new registered livestock facilities with less than 300 animal units.

Nonpoint Source Pollution Technical Assistance – KDHE

- a. Support Section 319 and Milford Lake Watershed RCPP implementation projects for nutrient management through reduction of phosphorus runoff from agricultural activities.
- b. Provide technical assistance on practices to establish vegetative buffer strips.
- c. Support implementation efforts of the Milford Lake WRAPS, and incorporate long term objectives of this TMDL into their 9-element watershed plans.
- d. Provide technical assistance on nutrient management for livestock facilities and practices which minimize impacts of small livestock operations in the watershed to reduce impacts to stream resources.

Milford Lake Watershed Regional Conservation Partnership Program (RCPP)

- a. Support implementation of BMPs, including nutrient management planning, cover crop planting, fencing, and improving access controls, through grants awarded by the Natural Resources Conservation Service (NRCS) and administered with the partnership of the Kansas Water Office.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – Kansas Department of Agriculture-Division of Conservation (KDA-DOC)

- a. Apply conservation farming practices—including no-till, terraces, and contours—and erosion control structures, including sediment control basins and constructed wetlands.
- b. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.
- c. Encourage residue management to reduce phosphorus loss and transport from cropland runoff in the watershed.
- d. Implement manure management plans.
- e. Install livestock waste management systems for manure storage.

Riparian Protection Program – KDA-DOC

- a. Protect, establish, or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
- b. Develop riparian restoration projects along targeted stream segments, especially those areas with base flow.
- c. Promote wetland construction to reduce runoff and assimilate loadings.
- d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

- a. Install grass buffer strips near streams.
- b. Leverage Conservation Reserve Enhancement Programs to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

- a. Educate agricultural producers on sediment, nutrient, and pasture management.
- b. Provide technical assistance on buffer strip design and minimizing cropland runoff.
- c. Encourage annual soil testing to determine capacity of field to hold phosphorus.
- d. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
- e. Promote and utilize the WRAPS efforts for pollution prevention, runoff control, and resource management.
- f. Educate livestock producers on livestock waste management, land-applied manure applications, and nutrient management plans.
- g. Provide technical assistance on livestock waste management systems and nutrient management plans.
- h. Repair or replace failing septic systems which are located within 100 feet of the Republican River or its tributaries.

Timeframe for Implementation

The WWTF operated by the City of Concordia (KS0025577) will be required to reduce nutrient loading to the Republican River. This facility currently has established nutrient goals; however, additional reduction strategies for this major municipal WWTF should be evaluated by 2021 with any necessary enhanced treatment initiated by the next permit starting in 2025. Rural runoff management should expand from 2020 to 2029 to ensure nutrients are addressed. Pollutant reduction practices should be installed within the priority sub-watersheds after 2019 with follow-up implementation and monitoring continuing through 2029.

Targeted Participants

The primary participant for implementation of this TMDL is the major municipal WWTF for the City of Concordia (KS0025577) and the Milford Lake WRAPS and RCPP. Agricultural operations immediately adjacent to the Republican River and its tributaries will be encouraged to implement appropriate practices to further reduce phosphorus loads. Watershed coordinators, technical staff of the WRAPS group, conservation district personnel, and county extension agents should coordinate to assess possible nutrient sources adjacent to streams. Implementation

activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient loading to the river.

Targeted agricultural activities to focus attention toward include:

1. Denuded riparian vegetation and poor riparian areas along the stream.
2. Conservation compliance on highly erodible areas.
3. Unbuffered cropland adjacent to the stream.
4. Total row crop acreage and gully locations.
5. No till or residue management on cropland.
6. Increasing no-till and precision agricultural practices, including cover crops.
7. Sites where drainage runs through or adjacent to livestock areas.
8. Sites where livestock have full access to the stream and it is their primary water supply.

Milestone for 2025

By 2025, advancement of necessary and appropriate measures to decrease phosphorus effluent in municipal WWTFs should be implemented. The Milford Lake WRAPS is currently (2019) beginning a three-year funding cycle to mitigate nutrient and sediment loads to the watershed, as well. This initiative seeks to reduce livestock impacts in the Buffalo Creek and implement agricultural BMPs over this time frame. By 2025, TP data from the station Republican River near Rice (SC510) should show indication of declining TP concentrations relative to the pre-2018 data.

Delivery Agents

The primary delivery agents for program participation will be the municipal WWTF, KDHE, and the Milford Lake WRAPS and RCPP.

Reasonable Assurances

Authorities

The following authorities may be used to direct activities in the watershed to reduce pollution:

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.
2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.
3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.
4. K.A.R. 28-16-69 through 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.
5. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation, and management of soil and water resources in the state, including riparian areas.
6. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

7. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.
8. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*, including selected WRAPS.
9. The *Kansas Water Plan* provides the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding

The State Water Plan annually generates \$12-13 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources by priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a **High Priority** area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients.

Effectiveness

Use of Biological Nutrient Removal technology in WWTFs has been well established to reduce nutrients, including phosphorus, in wastewater. Agricultural nutrient control has been proven effective through conservation tillage, contour farming, and use of grass waterways and buffer strips; additionally, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities. Presuming the Phase I milestone is not met, this TMDL will be evaluated after 2025 to assess the reductions in phosphorus loads that have taken place with guidance provided to targeted participants regarding follow-up implementation activities.

6. MONITORING

Monitoring for TP will continue at KDHE stations for the Republican River near Hardy, NE (SC231), Buffalo Creek near Concordia (SC509), Wolf Creek near Concordia (SC707), and Republican River near Rice (SC510). Biological monitoring will also continue for the Republican River stations near Hardy, NE (SB231) and Concordia (SB003) to assess compliance with the narrative nutrient criteria in the river. Based on the sampling data, the status of the watershed will be re-evaluated during the Section 303(d) listing process in 2032.

7. FEEDBACK

Public Notice

An active website is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and to provide specific TMDLs by river basin. This TMDL was posted to the Kansas-Lower Republican River Basin on this site on August 22, 2019 for public review.

Public Hearing

A public hearing on this TMDL was held on September 6, 2019 in Topeka, Kansas to receive public comments. No comments were received.

Milestone Evaluation

In 2029, evaluation will be made as to the degree of implementation that occurred within the watershed. Subsequent decisions will be made through consultation with local stakeholders and the WRAPS team regarding implementation of nonpoint source reduction strategies and development of additional implementation strategies for the watershed.

Consideration for Section 303(d) Delisting

The segments covered by this TMDL will be evaluated for delisting under Section 303(d) based on the monitoring data from 2020 to 2029. Therefore, the decision for delisting will ensue in the preparation for the 2030 Section 303(d) list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL, and implementation activities may be adjusted accordingly.

Incorporation into the TMDL Vision Process, Water Quality Management Plan, and the Kansas Water Planning Process

Under the current version of the Kansas TMDL Vision Process, the next anticipated revision of this TMDL will be after 2025. The revision will emphasize implementation of WRAPS activities and further reduction of nutrients in wastewater discharged by NPDES facilities. At that time, incorporation of this TMDL will be made into the WRAPS plan. Recommendations for this TMDL will be considered in the *Kansas Water Plan* implementation decisions under the State Water Planning Process for fiscal years 2020 to 2029.

Developed: February 4, 2020

REFERENCES

- Bureau of Reclamation, 2019, Bostwick Division, Accessed online at <https://www.usbr.gov/projects/index.php?id=502>.
- Electric Power Research Institute (EPRI), 2000. Advanced on-site wastewater treatment and management market study: Volume 2: State reports, TR-114870, Accessed online at <https://www.epri.com/#/pages/product/TR-114870/?lang=en-US&lang=en-US>.
- Hansen, C. V., 1997, Major components of flow in the Republican River during drought conditions from near Hardy, Nebraska, to Concordia, Kansas: Fact sheet 234-96, 6 p., Accessed online at <http://pubs.er.usgs.gov/publication/fs23496>.
- Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information, Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354, Accessed online at <https://www.mrlc.gov/nlcd2011.php>.
- Juracek, K., 2000, Estimation and comparison of potential runoff-contributing areas in Kansas using topographic, soil, and land-use information: U.S. Geological Survey Water-Resources Investigations Report 00-4177, 62 p., Accessed online at <https://ks.water.usgs.gov/pubs/reports/wrir.99-4242.html>.
- Kansas Department of Health and Environment, Bureau of Water, 2013, Kansas surface water register, 74 p., Accessed online at http://www.kdheks.gov/befs/download/Current_Kansas_Surface_Register.pdf.
- Kansas Department of Health and Environment, Bureau of Water, 2013, Kansas-Lower Republican Basin total maximum daily load: Milford Lake, Accessed online at http://www.kdheks.gov/tmdl/2013/Milford_TMDL.pdf.
- Kansas Department of Health and Environment, Bureau of Water, 2017, Kansas surface water quality standards: Tables of numeric criteria, 22 p., Accessed online at http://www.kdheks.gov/tmdl/download/SWQS_Tables_2017_12152017_final.pdf.
- Kansas Department of Health and Environment, Bureau of Water, 2018, 303(d) list of all impaired/potentially impaired waters, 90 p., Accessed online at http://www.kdheks.gov/tmdl/2018/2018_Proposed_List_All_impaired_waters_TF.pdf.
- Kansas Department of Health and Environment, Bureau of Water, 2018, Kansas surface water quality standards, 9 p., Accessed online at http://www.kdheks.gov/tmdl/download/SWQS_Regulations_Published_in_Kansas_Register.02.08.18.pdf.
- Kansas Department of Health and Environment, Bureau of Water 2018, Methodology for the evaluation and development of the 2018 section 303(d) list of impaired water bodies for Kansas, 38 p., Accessed online at http://www.kdheks.gov/tmdl/2018/2018_303_d_Methodology.pdf.
- Kansas Water Office, 2002, Population estimates and projections for cities by county by selected year.
- National Oceanic and Atmospheric Administration, 2019, Daily summary observations, Accessed online at <https://www.ncdc.noaa.gov/>.

- Perry, C.A., Wolock, D.M., and Artman, J.C., 2004, Estimates of flow duration, mean flow, and peak-discharge frequency values for Kansas stream locations: U.S. Geological Survey Scientific Investigations Report 2004-5033, 651 p., Accessed online at <https://ks.water.usgs.gov/stream-flow-statistics>.
- Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture, State Soil Geographic Database (STATSGO), Accessed online at <https://www.nrcs.usda.gov>.
- Tetra Tech, Inc. developed for U.S. Environmental Protection Agency, 2003, Spreadsheet Tool for Estimating Pollutant Load (STEPL), Accessed online at <https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl>.
- U.S. Census Bureau, 2010, 2010 Census Urban and Rural Classification, Accessed online at <https://www.census.gov/geo/reference/ua/urban-rural-2010.html>.
- U.S. Census Bureau, 2010, Fact Finder, Accessed online at https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk.
- U.S. Department of Agriculture, 2012, Census of Agriculture, Accessed online at https://www.agcensus.usda.gov/Publications/2012/Full_Report/Census_by_State/Kansas/.
- U.S. Department of Agriculture, 2019, Census of Agriculture, Accessed online at https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Kansas/.
- U.S. Environmental Protection Agency, 2000, Ambient water quality criteria recommendations: Rivers and streams in ecoregion VI, Accessed online at <https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-streams-documents>.
- U.S. Environmental Protection Agency, 2001, Ambient water quality criteria recommendations: Rivers and streams in ecoregion IV, Accessed online at <https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-streams-documents>.
- U.S. Environmental Protection Agency, 2001, Ambient water quality criteria recommendations: Rivers and streams in ecoregion V, Accessed online at <https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-streams-documents>.
- U.S. Environmental Protection Agency, 2000, Nutrient criteria technical guidance manual: Rivers and streams, Accessed online at <https://www.epa.gov/sites/production/files/2018-10/documents/nutrient-criteria-manual-rivers-streams.pdf>.
- U.S. Geological Survey, 2019, USGS WaterWatch, Accessed online at <http://waterwatch.usgs.gov>.
- Water Information Management and Analysis System (WIMAS), 2019, Accessible online at http://hercules.kgs.ku.edu/geohydro/wimas/query_setup.cfm.
- Wilson, B., Bartley, J., Emmons, K., Bagley, J., Wason, J., and Stankiewicz, S., 2005, Water information management and analysis system, Version 5, for the web—User manual: Open-file report 2005-30, Accessed online at http://hercules.kgs.ku.edu/geohydro/ofr/2005_30/wimas_ofr2005_30.pdf.

Appendix A

U.S. Environmental Protection Agency Level IV Ecoregions and Kansas Department of Health and Environment stream chemistry stations.

